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Proposal 06

VADIS/COST Forward Prediction Coding

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BBC(GB), CCETT(F), FI/DBP(D), Nokia(SF), NTL(GB), RAI(I), Retevision(E), Siemens(D), Telefonica(E), Telenorma(D), Telettra(I), TCE/DTB(D), UHannover(D), UPMadrid(E)

Documentation

CONTENTS.

1. Introduction.

This document gives a description of the "VADIS/COST Forward Predictive Coding" method. Much effort has been put into making the description "understandable". For that reason several figures have been included to illustrate coding principles rather than using mathematical notation for definitions. Where more detailed definitions are needed, reference is made to description using FORTRAN syntax.

When developing the model, three main guidelines were followed:

- To develop a method with inherent low coding delay to be suitable for "conversational" services.
- To define an "implementation friendly" method with low demands both on image memory and number of operations in the coding procedure. Yet, coding performance should not be sacrificed.
- To define a method as close to the existing standards H.261 and MPEG1 as possible in order to simplify interworking and benefit from common hardware development.

Optimizations have been made where we found significant gain. This was the case with the introduction of adaptive VLCs for transform coefficient coding for example. On the other hand we have omitted several other "tricks" that have given only marginal improvements.

This approach is thought to be in line with the intention of this phase of the MPEG2/CCITT work. It is to point out "promising" coding methods. It is believed that the detailed optimizations are better suited for the "convergence" phase after a test model has been established. The present method therefore gives considerable room for such optimizations and improvements.

2. General outline.

The main features of the coding method are:

- The full CCIR 601 format is coded.
- Hybrid DCT coding.
- Frame based coding.
- Every 10th frame is coded INTRA.
- Forward prediction from the previous frame.
- Field based calculation of integer pixel motion vectors.
- Motion vector range of ± 15.5 pixels, ± 7.5 lines (field based).
- INTRA prediction on block level.
- Adaptive use of 3 different VLC´s for coefficient coding.

3. Special characteristics of the method.

The main characteristics of the coding method are:

- Similar to H.261 and MPEG1 without interpolation. The main difference is the use of VLC codes for transform coefficients.

- Low coding delay due to only forward prediction.
- Low implementation complexity for the following reasons:
  - Only 2 frames stores are needed on the encoder side.
  - Only 1 frame store is needed on the decoder side.
  - The number of motion vectors needed is low due to one frame prediction.
  - Only one vector is calculated for each macroblock.
  - The integer pixel search for a frame block is performed using only one field of data.
  - The same encoder/decoder procedure is used for every frame.
- Good performance.

4. Picture Format.

The picture format is the 625 line, 50 Hz version of the 4:2:2 level of CCIR Recommendation 601 - 2.

In the simulations, the full 50 Hz version of the test sequences are coded without any kind of prepossessing. On the output side, the decoded pictures are presented without any post processing.

5. Layered structure of video data.

The coding method has five different layers. The different layers serve special functional purposes. This will be described in the following. The layering is also reflected in the data stream from the coder.

The different layers are visualized in Figure 1a. The corresponding data stream is indicated in Figure 1b is a syntax diagram. More details on the parameters shown in the syntax diagram will be described in connection with the definitions of the different coding modules.

5.1. Group Of Picture (GOP) layer.

A GOP consists of 10 pictures. The first picture is coded INTRA. The 9 following pictures may be predicted from the last pictures in the same GOP. The aim of the GOP is twofold: 1) It is possible to retrieve pictures from the stream of data with the time resolution of one GOP and 2). It assures a total refresh of data every GOP to prevent errors from accumulating.

5.2. PICTURE layer.

A picture consists of two fields of image data. Each picture starts with a picture start code to make resynchronization possible.

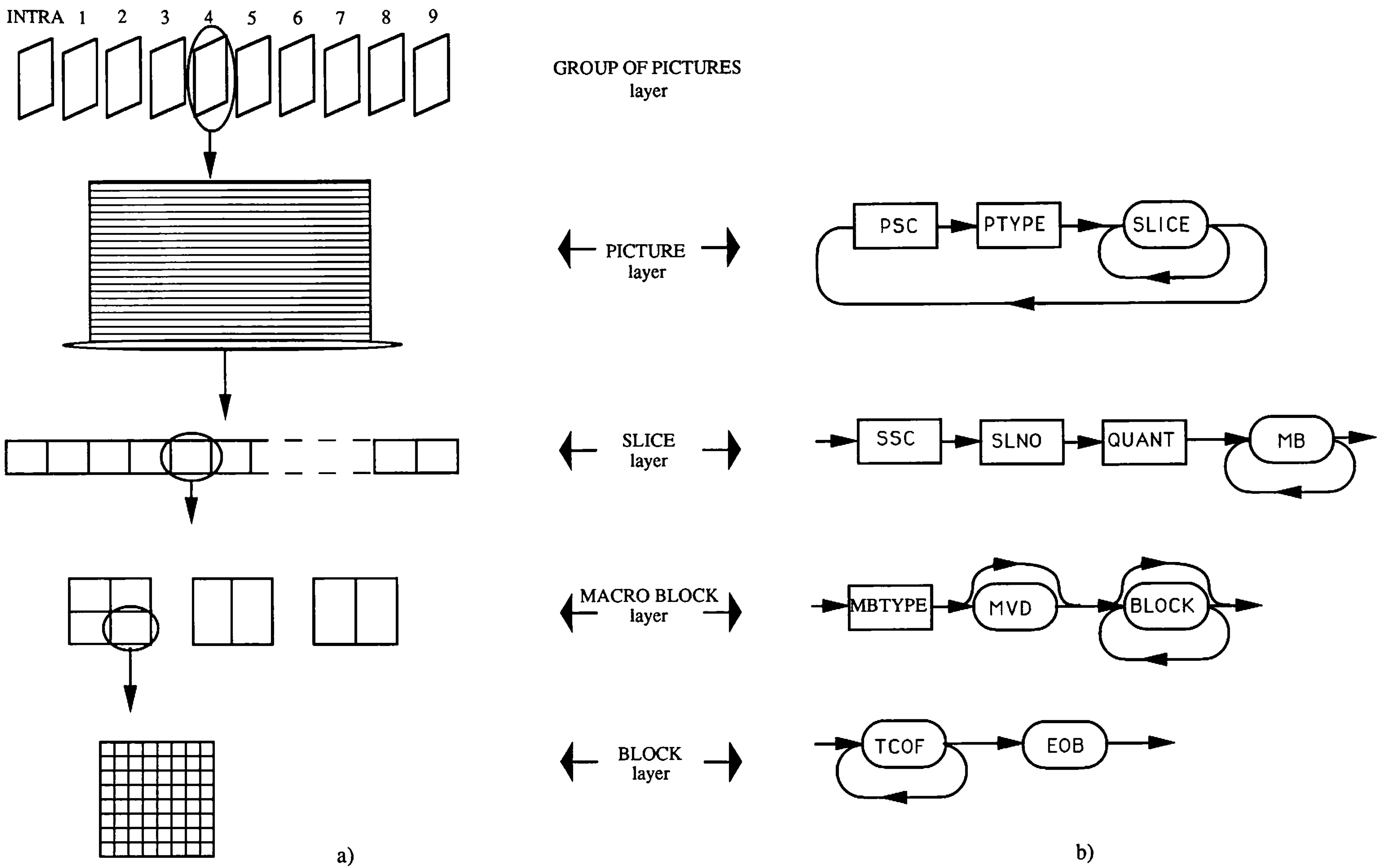
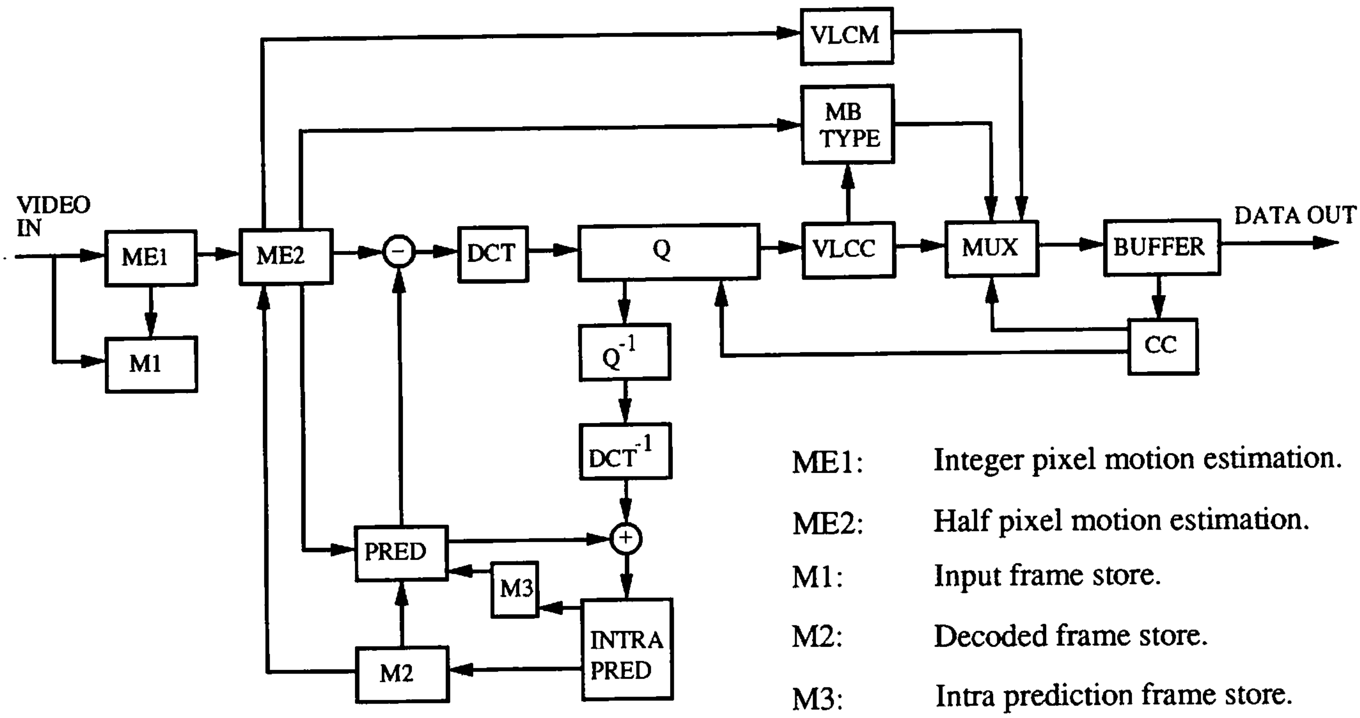
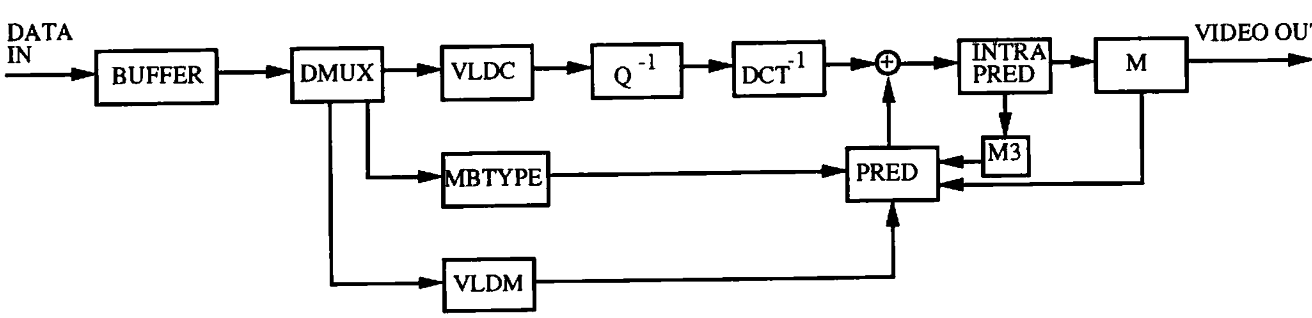


Figure 1. Layer structure. a) Visualization of layering. b) Syntax diagram of coded data.



ME1: Integer pixel motion estimation.
ME2: Half pixel motion estimation.
M1: Input frame store.
M2: Decoded frame store.
M3: Intra prediction frame store.
PRED: Make predicted block.
INTRA PRED: Save data for intra prediction.
VLCC: VLC coding of transform coefficients.
VLCM: VLC coding of motion vectors.
DCT: Discrete Cosine Transform.
Q: Quantizer.
CC: Coding control

(a)



VLDC: Variable Length Decoder for transform coefficients.
VLDM: " motion vectors.
M: Decoded frame store.

(b)

Figure 2. Block diagram of encoder (a) and decoder (b).

5.3. SLICE layer.

One picture consists of 36 SLICEs. Each SLICE starts with a synchronization word. Adjustment of quantization is done on the SLICE level. Information on the quantization is contained in the SLICE header.

5.4. MACROBLOCK - MB - layer.

One SLICE consists of 45 macroblocks. Determination of macroblock type (MBTYPE) is done on the MB level. Motion compensation and test on INTRA prediction is also performed at the MB level.

5.5. BLOCK layer.

One MB consists of four luminance 8•8 BLOCKs and four chrominance BLOCKs. Transformation, quantization and coding of transform coefficients is performed on the block level. INTRA prediction is also made on the BLOCK level.

For INTRA coding, a block may be either frame or field based. This will be explained in Section 7.3.

6. Block diagram of the encoder and decoder.

Figure 2 shows the block diagrams of the encoder and decoder. The different boxes are explained on the figure.

The block diagrams reflect the similarity to H.261.

The motion estimation is made in two steps (shown as ME1 and ME2). The first step (ME1) is an integer pixel search which is made relative to the noncoded frame (M1). The second step (ME2) is a half pixel search made relative to the decoded picture (M2). This second step makes the use of the "loopfilter" unnecessary.

As a result of these two step motion search, one exstra frame store is needed on the encoder side compared to H.261.

The other main difference from H.261 is the use of INTRA prediction (ref. INTRA PRED and M3 in the encoder block diagram). The prediction is made on the block level. Neighbouring "edge" points are used for the prediction. To do this, 4 sums of data are formed when decoding a block (INTRA PRED). These sums are stored in M3 for later use for prediction. The data have to be stored for one SLICE only. The size of M3 is therefore negligible compared to M1 and M2.

The operations in the different blocks of the block diagram will be explained in detail in the following sections.

7. Motion estimation.

An essential part of the coding method is to make a good prediction for the image blocks to be coded. The prediction is based on previously decoded picture material that is identical on the encoder and decoder sides to avoid the need for additional information. Motion estimation is made on the macroblock level. The main outcome from motion estimation is the prediction mode and - if required - the motion vector.

There are two main modes of prediction:

- INTER prediction where a macroblock is predicted from the previously decoded picture with a motion vector of half pixel accuracy.

- INTRA prediction. Each block is predicted from the neighbouring decoded pixels. There are two different INTRA predictions - frame based and field based.

Motion estimation is performed in two steps:
- Integer pixel search - including test on INTRA prediction.
- Half pixel search.

7.1. Integer pixel search.

The integer pixel search is made relative to noncoded picture. The resulting motion vector is used for a whole frame macroblock. The estimation, however, is performed on field 1 only. The reason for this is threefold:

- The dataflow through the motion estimator is reduced by a factor two.
- Motion estimation may be performed on the incoming picture data.
- The resulting performance differs negligibly from using the whole frame for estimation.

The estimation using only field 1 is illustrated in Figure 3. The field macroblock size for the integer motion search is 16 • 8. The search area is ± 15 pixels and ± 7 lines (field based).

INTRA prediction is also checked at this stage. For this purpose the 16 • 8 field macroblock is divided into two 8 • 8 blocks. For each of the blocks a constant prediction is made by the average of surrounding pixels. This is indicated in Figure 4 as the hatched areas pointing into each block. If one of the sets of 8 edge pixels is outside the picture, the average of the remaining 8 points is used. If all edge points are outside the picture, the constant prediction is set to 128.

The absolute difference from this prediction is compared with the differences obtained from the vectors of the integer motion search.

If the INTRA prediction gives the smallest absolute error, INTRA coding is used. If not we go to the half pixel search for motion vector to find the vector to be used for prediction. The decision INTRA/INTER prediction is therefore taken here.

The details of the actual operations to find the motion vectors is given in FORTRAN syntax in Section 14.2

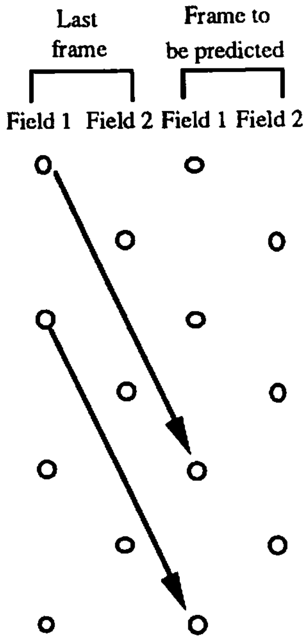
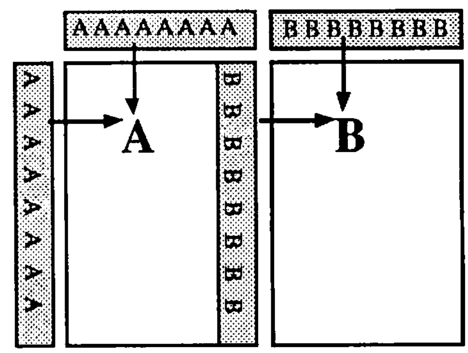


Figure 3. Only field 1 is used for integer motion estimation. In this example the vertical vector component is -2 field lines.



Prediction of **A** $= (\sum_{i=1}^{16} A)/16$

Prediction of **B** $= (\sum_{i=1}^{16} B)/16$

Figiure 4. Illustration of how boundary points are used for INTRA prediction.

7.2. Half pixel search.

If the previous search resulted in INTER, the half pixel search is made over a search window around the integer vector. The search on this level is made relative to the last decoded picture and the whole macroblock - 16•16 pixels - is used.

The search area is over 9 positions:
- ± 1/2 pixels in horizontal direction.
- ± 1/2 field line in vertical direction.

The search - and later prediction - is made so that the prediction of a pixel in a given field is based on pixels from the field of the same parity in the previous picture. This is illustrated in Figure 5.

Before the actual search, the half pixel version of an appropriate window of the decoded picture is made. The field 1 and field 2 parts of the "Last coded frame" in figure 5 may be considered to be separate parts with full frame line resolution.

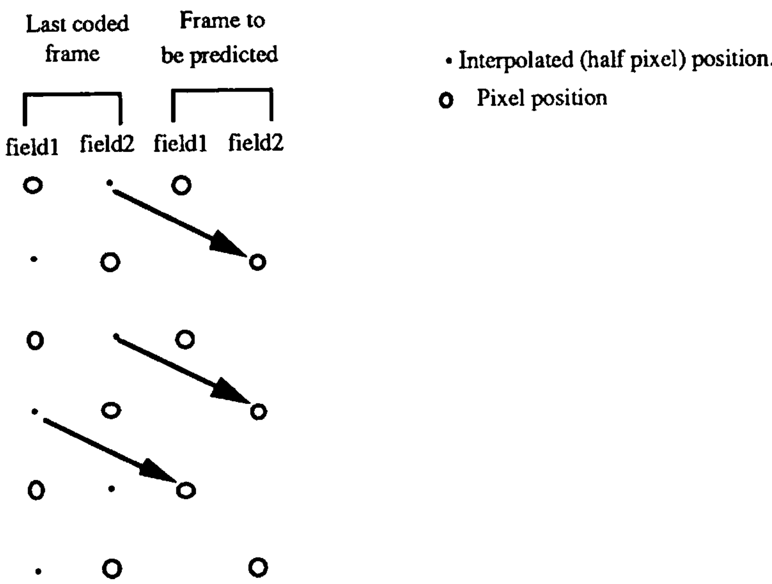
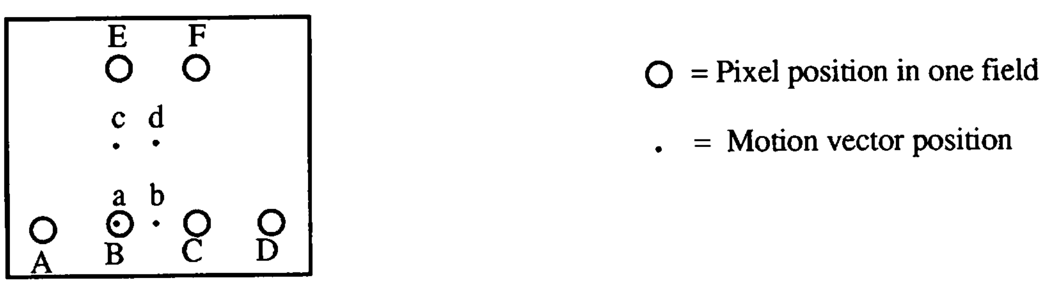


Figure 5. Illustration of how the half pixel prediction is done.

The interpolation in horizontal and vertical directions are shown in figure 6. In the vertical direction we see that the half pixel values are obtained by averaging the two adjacent field lines. In the horizontal direction, a "(-1,9,9,-1)/16" filter is used. This is to reduce the amount of filtering in the horizontal direction.



$a = B$ $\quad b = (9(B + C) - A - D)/16$

$c = (B + E)/2$ $\quad d = (B + C + E + F)/4$

Figure 6. Interpolation of half pixel luminance pixels. Capital letters indicate pixel values in the frame where the prediction is taken from. Lower case letters are interpolated values

The details of how the interpolation is made as well as the actual search is given in FORTRAN syntax in Section 14.3.

The outcome after the two steps of motion estimation is:

- Decision on INTRA or INTER coding.
- If INTER, the half pixel accuracy horizontal motion vector (range ±30), and the half field line (the same as frame line) accuracy vertical vector (range ±15).

7.3. Decision on frame or field coding for INTRA mode.

If a macroblock has been decided to be coded INTRA it is possible to do the coding either frame or field based. The reason for this distinction is the interlace picture format. If there is little or no motion in the picture, the two fields may be treated together. This results in frame coding. If on the other hand there is large motion in the image, lines from the same field will be more similar than adjacent lines from two different fields.

To make the decision, the energy (E) of the noncoded macroblock is calculated for two vertical frequencies:

$f = f_g$ - corresponding to the frame line frequency.
$f = f_{g/2}$ - corresponding to the field line frequency.

If the $E(f_g)$ is much larger than $E(f_{g/2})$ field coding is chosen. Otherwise frame coding is used.

The detailed calculation of the criteria is given in FORTRAN syntax in Section 14.4. Figure 7 illustrates the macroblock division.

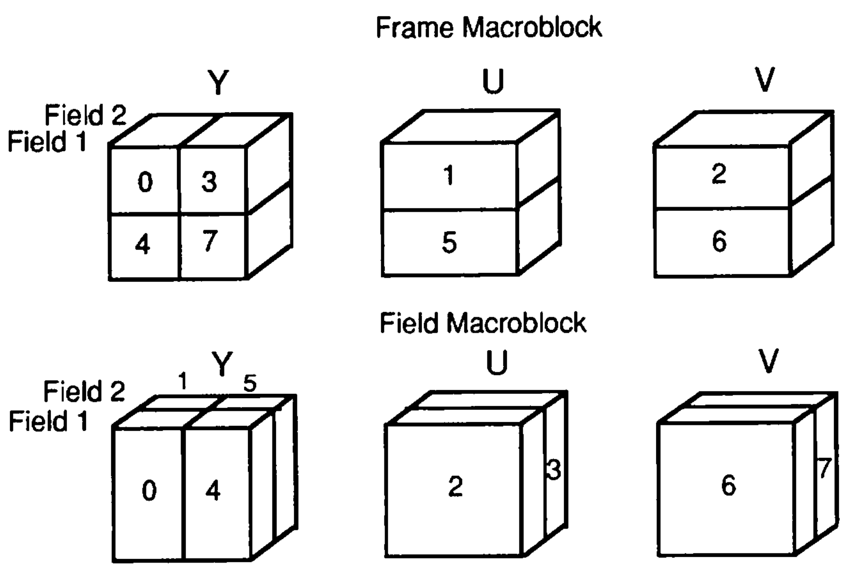


Figure 7. Division of a macroblock into 4 luminance and 4 chrominance blocks for frame and field coding.

8. Macroblock types (MBTYPE).

The table below shows the different macroblock types. MBTYPE defines the prediction modes that have been described previously. For MBTYPE = 3 it is assumed that the prediction is INTER with zero motion vector. This means that the new macroblock is represented by a copy of the corresponding macroblock of the previously decoded picture. The purpose of having this mode is to avoid using EOB codes (see later) when there is no additional information to be sent. The four macroblock types are transmitted to the decoder with a 2 bit fixed length codeword.

MBTYPE	PREDICTION
0	INTER
1	INTRA FRAME
2	INTRA FIELD
3	INTER, VECTOR=0, NO COEFFICIENTS.

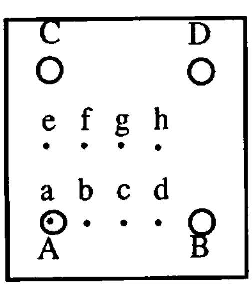
9. Prediction.

There are two basically different modes of prediction: INTER and INTRA.

9.1. INTER prediction.

On the encoder side the luminance prediction is automatically given from the second step of the motion estimation as the prediction that gives the lowest mean absolute difference (MAD). On the decoder side exactly the same interpolation is used to produce the same prediction as on the encoder side.

A prediction also has to be made for the chrominance blocks. The half pixel motion vectors used for luminance are also used for chrominance. The chrominance has half horizontal resolution compared with the luminance. Therefore we can not use the same horizontal interpolation as for luminance. The motion vectors have 1/4 resolution for the horizontal chrominance components. This is reflected in Figure 8 where the interpolation rules for chrominance are given. An exact definition is given with FORTRAN syntax in Section 14.5.



O = Pixel position in one field

. = Motion vector position

a = A
b = (3A + B)/4
c = (A + B)/2
d = (A + 3B)/4

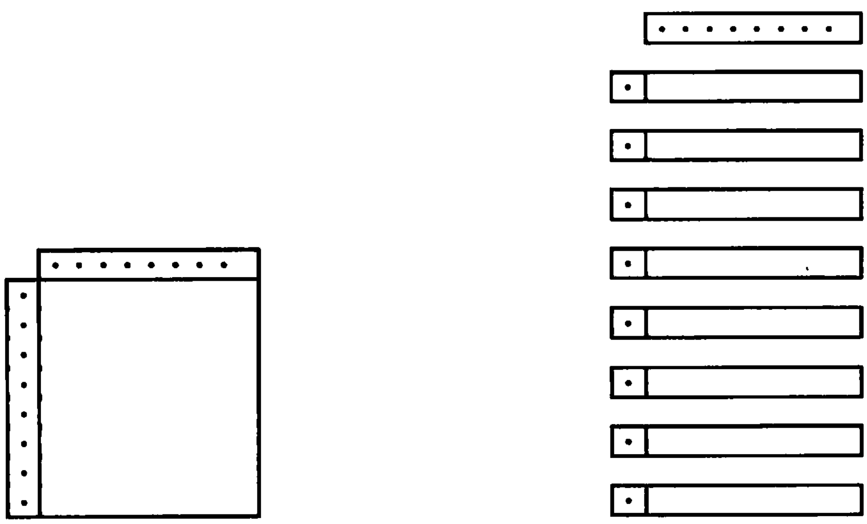
e = (A + C)/2
f = (3(A + C) + B + D)/8
g = (A + B + C + D)/4
h = (A + C +3(B + D))/8

Figure 8. Interpolation rules for chrominance prediction. Capital letters indicate pixel values in the frame where the prediction is taken from. Lower case letters are interpolated values.

9.2. INTRA prediction.

Whereas INTER prediction may be made on the macroblock level because the motion vectors are calculated on the MB level, the INTRA prediction has to be made specially for each block. The reason for this is that the prediction is best if it is based on pixels close to the block to be predicted. The prediction of an 8•8 block is therefore based on the 8 pixels right "above" the block and the 8 pixels to the "left" of the block as shown in figure 9. A constant value is obtained by averaging 16 "edge points". This value is used as a prediction for the whole block. If one of the sets of 8 edge pixels is outside the picture, the average of the remaining 8 points is used. If all edge points are outside the picture, the constant prediction is set to 128.

Distinction has to be made between frame and field prediction as shown in figure 9. The detailed description of the prediction is given in FORTRAN syntax in Section 14.6.



Frame based prediction. Field based prediction.

Figure 9. Illustration of INTRA prediction. The whole block (field or frame) is predicted by the average value: $PRED = (\sum_{i=1}^{16} \bullet)/16.$

10. Transformation.

For each 8•8 block - luminance or chrominance - a difference block containing the differences between the block values to be coded and the prediction is formed. A two dimensional DCT is then applied to the block differences. The relation between the block differences and the transform coefficients are given by:

$$TC(k,l) = \frac{1}{4}\, C_k\, C_l \sum_{i=0}^{7} \sum_{j=0}^{7} BD(i,j)\, \cos\frac{\pi(2i+1)k}{16}\, \cos\frac{\pi(2j+1)l}{16}$$

$$BD(i,j) = \frac{1}{4} \sum_{k=0}^{7} \sum_{l=0}^{7} C_k\, C_l\, TC(k,l)\, \cos\frac{\pi(2i+1)k}{16}\, \cos\frac{\pi(2j+1)l}{16}$$

where:

BD(i,j) is an element in the 8•8 block difference.

TC(k,l) is a coefficient of the 8•8 transformed block.

$C_w = \frac{1}{\sqrt{2}}$ for $w = 0$

$C_w = 1$ for $w \neq 0$

11. Scanning of transform coefficients.

There are different scanning paths for luminance and chrominance. The same scanning path is used for frame and field coding. The scanning paths are given below:

LUMINANCE

0	2	6	12	20	28	36	44
1	5	11	19	27	35	43	51
3	7	13	21	29	37	45	52
4	10	18	26	34	42	50	57
8	14	22	30	38	46	53	58
9	17	25	33	41	49	56	61
15	23	31	39	47	54	59	62
16	24	32	40	48	55	60	63

CHROMINANCE

0	2	3	9	10	20	21	35
1	4	8	11	19	22	34	36
5	7	12	18	23	33	37	48
6	13	17	24	32	38	47	49
14	16	25	31	39	46	50	57
15	26	30	40	45	51	56	58
27	29	41	44	52	55	59	62
28	42	43	53	54	60	61	63

Figure 10. Scanning paths for luminance and chrominance.

12. Quantization.

The actual reduction of information to be generated from an image is the result of quantization of transform coefficients. It is therefore very important that this is done in an efficient way. The quantizer should be designed to give "optimum quality performance with a given bit generation" or equivalently "minimum bit generation for a given quality performance". This is close to the wording being used in Rate Distortion Theory. It means that to get an optimum solution, quantization and subsequent line coding of the quantized values must be designed together. Such an optimization has been attempted in the present coding method. The resulting quantization mechanism is described in the following sections.

12.1. The exponential set of quantizer stepsizes.

The method uses 49 quantizer stepsizes (QS) for quantizing transform coefficients. The quantizer stepsize increases exponentially. The value is doubled for every 5 steps. The possible values of the stepsizes are given as an array:

QS(NQUANT), NQUANT = 1,49

The values of the array are:

2	2	3	3	3	4	5	5	6	7
8	9	11	12	14	16	18	21	24	28
32	37	42	49	56	64	74	84	97	111
128	147	169	194	223	256	294	338	388	446
512	588	676	776	891	1024	1176	1351	1552	

12.2. The linear quantizer.

The quantizer is linear in the sense that for a given quantizer stepsize QS(NQUANT) the possible reconstruction values for the transform coefficient are:

LEVEL•QS(NQUANT), LEVEL is an integer.

The decision levels for the quantizer can be chosen by the encoder. In the present method the decision levels are equally spaced except around zero. The quantizer is illustrated in figure 11.

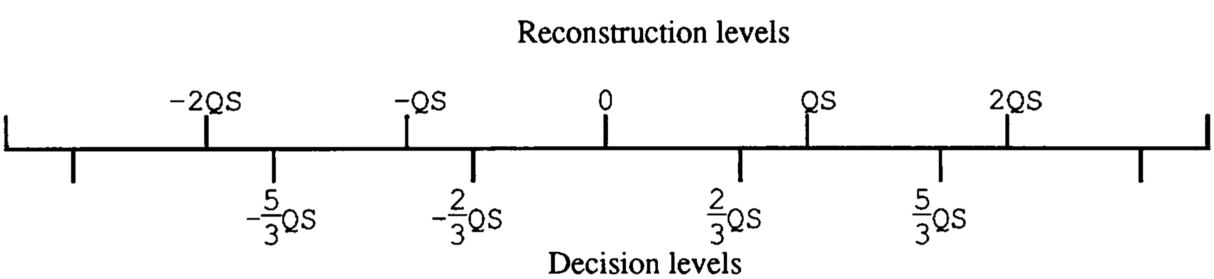


Figure 11. Decision and reconstruction levels for the quantizer with a quantizer stepsize QS.

12.3. The quantizer stepsizes.

For a given transform coefficient one of the quantizer stepsizes from QS(NQUANT) has to be chosen. NQUANT is given by:

NQUANT = QUANT + MQUANT

QUANT is a parameter coming from from the coding control. It is updated once every SLICE. The values are in the range: 1,31.

MQUANT is an addition depending on the coefficient number. It is introduced to give a quantization that is more in accordance with the human visual system. MQUANT is different for luminance and chrominance. The values are given in the table below. The listing is according to transform coefficient position.

0	0	1	2	4	7	10	12
0	1	2	4	7	10	12	13
1	2	4	7	10	12	13	14
2	4	6	9	11	12	14	15
3	6	9	11	12	13	15	16
5	8	11	12	13	14	15	16
6	10	11	12	14	15	15	16
6	11	12	13	14	15	16	16

Quantization matrix LUMINANCE

0	0	1	3	5	8	11	14
0	1	3	5	8	11	14	15
1	3	5	8	11	14	15	16
3	5	8	11	14	15	16	17
5	8	11	14	15	16	17	18
8	11	14	15	16	17	18	18
9	13	15	16	17	18	18	18
9	15	16	17	18	18	18	18

Quantization matrix CHROMINANCE.

The quantization/dequantization can be given on mathematical form:

$$\text{LEVEL} = \text{SIGN}(\text{TC}(k,l)) \bullet (|\text{TC}(k,l)| + \frac{2}{3}\text{QS}(\text{NQUANT}))/\text{QS}(\text{NQUANT})$$

$$\text{TCQ}(k,l) = \text{LEVEL} \bullet \text{QS}(\text{NQUANT})$$

LEVEL is the parameter to be coded and sent to the decoder (together with RUN - the number of zero coefficients since the last nonzero coefficient).

TC(k,l) is the transform coefficient and TCQ(k,l) the reconstructed value of the transform coefficient.

The details of quantization, dequantization (and decision of VLC table to be used) is given in FORTRAN syntax in Section 14.7.

13. Coding.

This section deals with the production of the codes - and thereby bitstream to be transmitted. The bitstream is composed of SYNCHRONIZATION codes and coded INFORMATION data. The description will follow the Syntax diagram in figure 1b.

13.1. Synchronization codes.

The purpose of synchronization codes is to be able to restart decoding of image data when entering the bitstream at an arbitrary point. To be able to do this, the sync. words must be unique in the sense that the bit combination can not be created by the coding of image data.

The synchronization words used consist of a number of zeros followed by a 1. It is therefore of interest to know how many consecutive zeros may be produced by the image data. For the present method this turns out to be 12. This means that any codeword with more than 12 zeros followed by a 1 can be used as synchronization word.

Two syncronization codes are used in this method:

```
Picture Start Code PSC 0000 0000 0000 0000 0000 0000 0000 0001

Slice Start Code SSC   0000 0000 0000 0001
```

13.2. Fixed length codes.

The following fixed length codes are used:

Parameter	No. of bits	Value	Code
Picture type PTYPE	1	0 INTRA 1 INTER	0 1
Slice number SLNO	6	1 . 36	100000 . 001001
Quantizer number QUANT	5	1 . 31	10000 . 11111
MBTYPE	2	0 INTER 1 INTRA, FRAME 2 INTRA, FIELD 3 NO CODING	00 10 01 11

13.3. Variable length codes.

There are two parameters being coded by variable length codes. Those are the Motion Vector Differences (MVD) and the transform coefficients (TCOF).

13.3.1. MVD codes.

The motion vector differences are coded as in MPEG1. It means that the horizontal and vertical components are coded relative to the values of the previous macroblock. For the first macroblock in a SLICE the reference is to the zero vector. The table below gives the codewords used for vertical and horizontal motion vector differences.

Interpretation of the bits "s" and "b":

"s" is a sign bit.
s = 0, Positive "Little" or negative "Big" value.
s = 1, Negative "Little" or positive "Big" value

"b" is an extension bit used for the horizontal component only
b = 0 for odd values.
b = 1 for even values.

MVD code	Vertical MVD values.		Horizontal MVD values.	
	Little	Big	Little	Big
1	0		0	
01sb	±1		±(1,2)	± 62
001s b	±2,	±30	±(3,4),	±(60,61)
0001 sb	±3,	±29	±(5,6),	±(58,59)
0000 11sb	±4,	±28	±(7,8),	±(56,57)
0000 101s b	±5,	±27	±(9,10),	±(54,55)
0000 100s b	±6,	±26	±(11,12),	±(52,53)
0000 011s b	±7,	±25	±(13,14),	±(50,51)
0000 0101 1sb	±8,	±24	±(15,16),	±(48,49)
0000 0101 0sb	±9,	±23	±(17,18),	±(46,47)
0000 0100 1sb	±10,	±22	±(19,20),	±(44,45)
0000 0100 01sb	±11,	+21	±(21,22),	±(42,43)
0000 0100 00sb	±12,	±20	±(23,24),	±(40,41)
0000 0011 11sb	±13,	±19	±(25,26),	±(38,39)
0000 0011 10sb	±14,	±18	±(27,28),	±(36,37)
0000 0011 01sb	±15,	±17	±(29,30),	±(34,35)
0000 0011 00sb	-16,	16	±31,-32 ,	32,±33

13.3.2. Transform coefficient codes.

The transform coefficients are coded using two-dimensional VLC tables. The coefficients are scanned according to the scanning paths given by the numbering in figure 10. For nonzero coefficients a pair of (LEVEL,RUN) is obtained. This pair is coded using one of three VLC tables shown in figure 12. The number of bits for the different combinations of LEVEL and RUN for the three different VLC tables are indicated in the table below.

```
         LEVEL
   4  7  8  8  9 10 11 11 .
R  5  9 10 11 12  .  .
   5 10 11 12  .  .
U  6 11 12  .  .
   6 12 13  .  .
N  7 13  .  .
   7  .  .
   7  .  .
   7  .  .
   8  .
   .      1 bit for EOB
```

```
         LEVEL
   3  5  6  8  8  9 10 11 .
R  4  7  8  9  .  .
   5  8  9  .  .
U  5  9 10  .  .
   5 10  .  .
N  7 11  .  .
   7  .  .
   7  .  .
   7  .  .
   8  .
   .      3 bitS for EOB
```

```
         LEVEL
   2  4  5  6  6  7  8  8 .
R  5  6  7  8  .  .
   6  7  8  .  .
U  7  8  9  .  .
   7  9  .  .
N  7 10  .  .
   7  .  .
   7  .  .
   7  .  .
   8  .
   .      5 bitS for EOB
```

13.3.2.1. Decision of VLC table.

The VLC tables are numbered 0,1,2. The decision of VLC table is done in the same way but separately for luminance and chrominance. The following description therefore holds for both luminance and chrominance.

The first coefficient of a block is coded using table VLC = VLC0.

- For the first macroblock of a SLICE VLC0 = 0.

- For the remaining macroblocks:
  VLC0 ≐ COEFFLAST/16 (limited to 0-2)
  COEFFLAST is the number of nonzero coefficients in the last macroblock.

When a nonzero coefficient is found, the VLC table to be used for the next codeword is:

VLC = (2•LEVEL + VLC0 - RUN/4 - 1)/2, limited to (0-2).

The details of the decision procedure is also given in FORTRAN syntax in Section 14.7.

13.3.2.2. Definition of VLC tables.

The VLC tables in figure 12 have 15 codewords that are different for the three tables - including three escape codes. These escape codes point at three different regions as shown in figure 12. The 15 codewords for the three VLC tables are listed in the table below.

PARAMETER TO BE CODED	CODEWORD (S is sign bit)		
	VLC0	VLC1	VLC2
EOB	1	101	0001 0
ESC1	0000 001	0000 001	0011
ESC2	0000 10	0101	011
ESC3	010	100	100
RUN=4, LEVEL=1	0001 0S	0010 S	0000 10S
RUN=3, LEVEL=1	0001 1S	0011 S	0000 11S
RUN=2, LEVEL=1	0010 S	0100 S	0001 1S
RUN=1, LEVEL=1	0011 S	011S	0101 S
RUN=0, LEVEL=1	011S	11S	11S
RUN=0, LEVEL=2	0000 11S	0001 S	101S
RUN=0, LEVEL=3	0000 011S	0000 1S	0100 S
RUN=0, LEVEL=4	0000 010S	0000 011S	0010 1S
RUN=0, LEVEL=5	0000 0001 S	0000 010S	0010 0S
RUN=0, LEVEL=6	0000 0000 1S	0000 0001 S	0000 01S
RUN=0, LEVEL=7	0000 0000 01S	0000 0000 1S	0000 001S

The codes for the three regions (I-III) are:

I:
The total code may be described as: ESC1 - LEAST2 - ONES - ZERO - SIGN.

ESC1 is the escape code to the region.
LEAST2 are the two least significant bits in the value of LEVEL.
ONES is a variable number of "1"s. The number is (LEVEL-8)/4
ZERO is a zero bit.
SIGN is the sign bit of LEVEL.

II:
The code for this region is: ESC2 - ONESL - ZEROL - SIGN - ONESR - ZEROR

ESC2 is the escape code to the region.
ONESL is a variable number of "1"s. The number is LEVEL-2
ZEROL is a zero bit.
SIGN is the sign bit of LEVEL.
ONESR is a variable number of "1"s. The number is RUN - 1.
ZEROR is a zero bit.

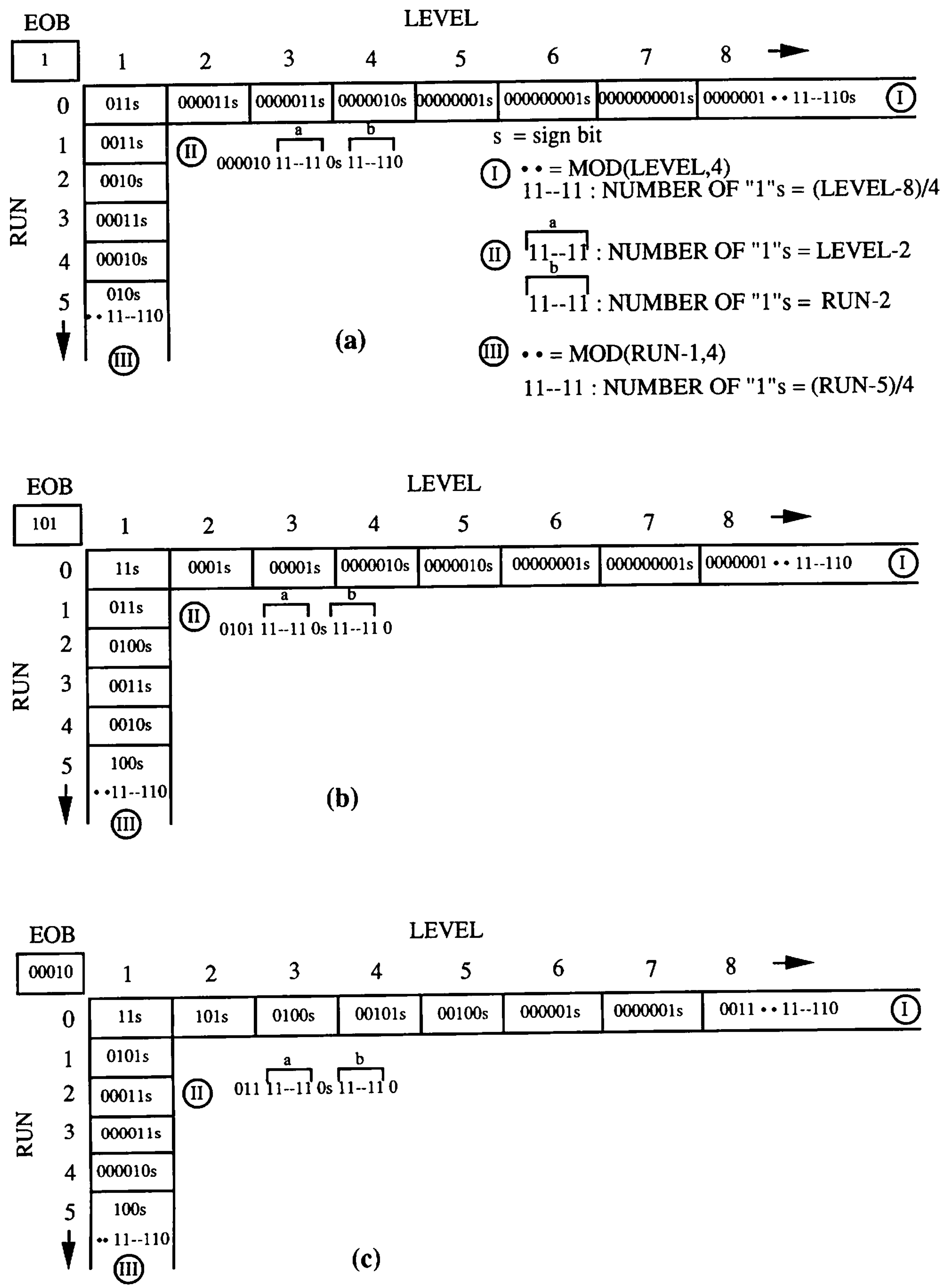


Figure 12. VLC tables for transform coefficient coding: (a) with 1 bit for EOB. (b) with 3 bits for EOB and (c) with 5 bits for EOB.

III:
The code for this region is: ESC3 - SIGN - LEAST2 - ONES - ZERO

ESC3 is the escape code to the region.
SIGN is the sign bit of LEVEL.
LEAST2 are the two least significant bits of (RUN-1).
ONES is a variable number of "1"s. The number is (RUN-5)/4
ZERO is a zero bit.

14. Documentation of specific computations with FORTRAN syntax.

In this section some of the computational details of the coding method is given in FORTRAN syntax. This is to give an exact definition of the computations made in the model. FORTRAN is chosen because the model is programmed in FORTRAN. The statements given in this section are not taken from the source code of the actual program. The purpose has not been to produce an optimal code, but rather that the FORTRAN syntax shall provide an exact and easily understandable definition of details in the method. No attempt has been made to produce "economical" codes. The statements in this section should therefore not be used for evaluating number of operations etc. for the method.

14.1. Terminology.

```
ARRAYS:

FRAME().             Luminance frame.  The numbering of lines is frame based.
CFRAME()             Chrominance frame.  The U and V components are located in
                     alternate positions.  U at even addresses, V at odd
                     addresses.
BLOCK(0:15,0:15):    Original luminance macroblock.
PREDY(-2:31,-2:33,0:1)
                     Luminance prediction with 1/2 pixel accuracy.
PREDC(0:15,0:15)     Chrominance prediction with 1/2 pixel accuracy.

PARAMETERS:

H0:  Horizontal position of the macro block.
V0:  Vertical   position of the macro block.

HI:  Horizontal integer pixel displacement.
VI:  Vertical   integer pixel displacement.

H2:  Total horizontal motion vector with 1/2 pixel accuracy).
V2:  Total vertical   motion vector with 1/2 pixel accuracy).

INTRA_PREDICTION:  =1 for FIELD prediction, =2 for FRAME prediction.
```

14.2. Test on INTRA prediction and integer pixel motion search.

14.2.1. Test on INTRA prediction.

14.2.1.1. Calculate DC values.

```
DO J = 0,8,8
  SUM = 0
  DO I = 0,7
    SUM = SUM + FRAME (H0 + I + J,V0 - 2) + FRAME(H0 - 1 + J,V0 +2*I)
  END DO
  DC(J/8) = SUM/16
END DO
```

OUTCOME: DC(0:1)

14.2.1.2. Finding the error.

```
ERROR_INTRA = 0
DO PIXEL = 0,15
  DCNUMBER = PIXEL/8
  DO LINE = 0,14,2
    ERROR_INTRA = ERROR_INTRA + IABS(BLOCK(PIXEL,LINE) - DC(DCNUMBER))
  END DO
END DO
```

OUTCOME: ERROR_INTRA

14.2.2. Integer motion search.

```
ERROR0 = 100000
DO H = -15,15
  DO V = -7,7
    ERROR=0
    DO LINE = 0,14,2
      DO PIXEL = 0,15
        ERROR = ERROR + IABS(BLOCK(PIXEL,LINE)-FRAME(H0+H+PIXEL,V0+V+LINE))
      END DO
    END DO
    IF(ERROR.LT.ERROR0) THEN
      HI=H
      VI=V
      ERROR0=ERROR
    END IF
  END DO
END DO
```

OUTCOME: HI,VI

14.3. Half pixel search

14.3.1. Creation of the half pixel array.

```
DO FIELD = 0,1
  DO LINE = FIELD-2,16,2
    P2 = 2*PIXEL
    DO PIXEL = -1,15
      L2 = LINE*2
      PREDY(P2  ,L2  ,FIELD) =   FRAME(H0+HI+PIXEL  ,V0+VI+LINE  )
      PREDY(P2  ,L2+1,FIELD) =  (FRAME(H0+HI+PIXEL  ,V0+VI+LINE  )
                               + FRAME(H0+HI+PIXEL  ,V0+VI+LINE+2))/2
      PREDY(P2+1,L2  ,FIELD) =(9*FRAME(H0+HI+PIXEL  ,V0+VI+LINE  )
                              +9*FRAME(H0+HI+PIXEL+1,V0+VI+LINE  )
                               - FRAME(H0+HI+PIXEL-1,V0+VI+LINE  )
                               - FRAME(H0+HI+PIXEL+2,V0+VI+LINE  ))/16
      PREDY(P2+1,L2+1,FIELD) =  (FRAME(H0+HI+PIXEL  ,V0+VI+LINE  )
                               + FRAME(H0+HI+PIXEL+1,V0+VI+LINE  )
                               + FRAME(H0+HI+PIXEL+1,V0+VI+LINE+2)
                               + FRAME(H0+HI+PIXEL  ,V0+VI+LINE+2))/4

    END DO
  END DO
END DO
```

OUTCOME: PREDY()

14.3.2. Motion search for half pixel accuracy.

```
ERROR0 = 100000
DO VER = -1,1
  DO HOR = -1,1
    ERROR=0.
    DO FIELD = 0,1
      DO LINE = FIELD,15,2
        DO PIXEL = 0,15
          ERROR = ERROR +IABS(BLOCK (  PIXEL,      LINE            )-
                              PREDY(2*PIXEL+HOR,2*LINE+VER,FIELD))
        END DO
      END DO
    END DO
    IF(ERROR.LE.ERROR0) THEN
      VER0 = VER
      HOR0 = HOR
      ERROR0 = ERROR
    END IF
  END DO
END DO

H2 = 2*HI + HOR0
V2 = 2*VI + VER0
```

OUTCOME: H2,V2

14.4. Decision on frame or field coding for INTRA mode.

```
SUM1 = 0
SUM2 = 0
DO PIXEL = 0,15
  DO LINE = 0,15,2
    SUM1 = SUM1 + (BLOCK(PIXEL,LINE    ) - BLOCK(PIXEL,LINE + 1))
  END DO
  DO LINE = 0,15,4
    SUM2 = SUM2 + (BLOCK(PIXEL,LINE    ) + BLOCK(PIXEL,LINE + 1)
                 - BLOCK(PIXEL,LINE +2) - BLOCK(PIXEL,LINE + 3))
  END DO
END DO
IF(SUM1.GT.(512 + SUM2)) THEN
  INTRA_PREDICTION = 1
ELSE
  INTRA_PREDICTION = 2
END IF
```

OUTCOME: INTRA_PREDICTION. 1 means Field coding.
2 means Frame coding.

14.5. Chrominance interpolation.

HCINTEGER: Integer part of horizontal motion vector for chrominance.
VCINTEGER: Integer part of vertical motion vector for chrominance.
MODE: Defines one of 8 interpolation methods for chrominance.

```
HCINTEGER = H2.AND.-4
VCINTEGER = V2.AND.-2

MODE = H2.AND.3 + 4*(V2.AND.1) + 1

DO 10 LINE = 0,15
  L = V0 + LINE + VCINTEGER
  DO 10 PIXEL = 0,15
    P = H0 + PIXEL + HCINTEGER
    GOTO(1,2,3,4,5,6,7,8) MODE
1   PREDC(PIXEL,LINE) =     CFRAME(P  ,L  )
    GO TO 10
2   PREDC(PIXEL,LINE) =  (3*CFRAME(P  ,L  ) +   CFRAME(P+2,L  ))/4
    GO TO 10
3   PREDC(PIXEL,LINE) =  (  CFRAME(P  ,L  ) +   CFRAME(P+2,L  ))/2
    GO TO 10
4   PREDC(PIXEL,LINE) =  (  CFRAME(P  ,L  ) + 3*CFRAME(P+2,L  ))/4
    GO TO 10
5   PREDC(PIXEL,LINE) =  (  CFRAME(P  ,L  ) +   CFRAME(P  ,L+2))/2
    GO TO 10
6   PREDC(PIXEL,LINE) = (3*(CFRAME(P  ,L  ) +   CFRAME(P  ,L+2)) +
                            CFRAME(P+2,L  ) +   CFRAME(P+2,L+2)))/8
    GO TO 10
7   PREDC(PIXEL,LINE) = (   CFRAME(P  ,L  ) +   CFRAME(P  ,L+2) +
                            CFRAME(P+2,L  ) +   CFRAME(P+2,L+2))/4
    GO TO 10
8   PREDC(PIXEL,LINE) = (   CFRAME(P  ,L  ) +   CFRAME(P  ,L+2) +
                         3*(CFRAME(P+2,L  ) +   CFRAME(P+2,L+2)))/8
10  CONTINUE
```

OUTCOME: PREDC()

14.6. INTRA prediction of a frame or field block.

```
SUM = 0
DO 7 I = 0,7
  SUM = SUM + FRAME(H0 + I,V0 - INTRA_PREDICTION) +
              FRAME(H0 - 1,V0 + INTRA_PREDICTION*I)
END DO
DCPRED = SUM/16
```

OUTCOME: DCPRED

14.7. Quantization and decision of VLC to be used.

```
COEFF(0:63):        Transform coefficients for a block..
QCOEFF(0:63):       Quantized coefficients for a block.
MQUANT(0:63):       Qantization additions according to coefficient.number.
QS(0:49):           Quantizer stepsize values.

QUANT               Number of quantizer step size from the controller.
COEFFLAST            Number of nonzero coefficients in the last macroblock.
```

```
RUN = -1
VLC0 = MIN0(2,COEFFLAST/16)
VLCN = VLC0

DO K = 0,63
  RUN = RUN + 1
  NQUANT = QUANT + MQUANT(K)
  N = (IABS(COEFF(K))+QS(NQUANT)/3)/QS(NQUANT)
  IF(N.GT.0) THEN
    N and RUN are coded with VLC table number VLCN.
    VLCN = MIN0(2,MAX0(0,(N + N + VLC0 - RUN/4 -1)/2))
    RUN = -1
  END IF
  QCOEFF(K) = ISIGN(N*QS(QUANT),COEFF(K))
END DO
EOB is coded according to VLC table no VLCN.
```

15. Compatibility features.

As already stated, the present coding method has great similarity to H.261 and MPEG1. This means that modules used in these standards can also be used in the present method. The main common modules are:

- DCT and inverse DCT chips.
- Integer part of motion estimation.
- VLC coding of motion vector differences.

The bitstream produced by the present method is not compatible with bitstreams produced by H.261 or MPEG1.

15.1. Compatibility by simulcast.

Compatibility with H.261 and MPEG1 may be obtained by simulcast. It is assumed that 1 Mbit is used for H.261 or MPEG1 and the rest of the bitrate for the new method. Possible assignments of bitrates are shown in the table below.

Total bitrate	Bitrate for H.261/MPEG1	Bitrate for new method
4	1	3
9	1	8

For full compatibility, the encoder must be able to produce bitstreams according to (H.261/MPEG1) in addition to bitstreams according to the new method. Likewise, the decoder must be able to decode the (H.261/MPEG1) bitstream in addition to bitstreams according to the new method. These additional requirements are not contained in the previous description of the present coding method.

Simulated sequences with bitrates of 3 Mbit will be shown on D1 tape. This is to demonstrate the picture quality when the total bitrate is 4 Mbit and 1 Mbit is spent on the (H.261/MPEG1) bitstream.

16. Fast forward/backward.

The coding method has a random access feature which makes fast forward and fast backward possible. This is achieved by decoding and displaying all or a subset of the regularly INTRA coded pictures in the sequence.

It is assumed that for the fast forward/backward mode the bitrate from the storage media to the decoder is not exceeding the bitrate at normal playback. One INTRA frame may take up to 40% of the average number of bits spent on a GOP. One way to obtain fast forward/backward is therefore to display every decoded INTRA picture four times - corresponding to 160 milliseconds.

This mode of displaying every INTRA frame four times provides a possibility of fast forward/backward with a speed of 2.5 times normal playback speed. This will be demonstrated on D1 tape. If every N INTRA coded frame is decoded and displayed four times, fast forward/backward with a speed of N•2.5 times normal playback speed may be obtained.

17. Coding/decoding delay.

In this section there will first be a definition of coding/decoding delay. This is followed by documentation of the delay resulting from the presented coding method. Finally there is a description of a different way of choosing macroblock type (MBTYPE) on the encoder side in order to reduce coding/decoding delay.

17.1. Definition of coding/decoding delay.

The definitions given here applies for the present method with forward prediction only. For other coding methods - for example including frame interpolation - it does not apply.
There are many ways of defining coding/decoding delay. Before stating numeric values for the present coding method, it is necessary to define the different parts included in the total delay.

It is not trivial to give a good definition of delay. The definition used here is visualized in figures 13 and 14. Before going into the definition, there are some assumptions to be stated:

- There is a channel between encoder and decoder with a constant bitrate.
- On the encoder side the coder uses one picture period to code a picture. It spends an equal amunt of time on each macroblock. The resulting bits (variable number for each MB) are put into a buffer.
- Likewise the decoder reads bits from a decoder buffer, uses one frame period to decode a picture and spends the same time to decode each macroblock.
- Every picture is displayed on the decoder side.
- The buffers on the encoder and decoder sides are equally large. Their size is measured in time - that is how long it takes to empty/fill the buffer with the constant channel bitrate.
- The encoder has means to control the number of produced bits so that the encoder buffer never gets empty and never reaches overflow.
- Transmission time from encoder to decoder is assumed to be zero.

Figure 13 illustrates the filling of encoder and decoder buffers taking the above assumptions into account. The encoder starts to produce bits and to put them into the encoder buffer at Time = 0. The transmission to the decoder is started at the same time. The decoder waits until the decoder buffer is full before starting the decoding (and thereby extracting bits from the buffer). The time between the start of encoding and start of decoding is therefore equal to the buffersize. From figure 13 it is seen that this procedure ensures that the bits are always available at the decoder side when they are needed. This is the same as saying that the decoder buffer never gets empty and never overflows.

Figure 14 shows the different contributions to the total delay. Some assumptions are made:

- On the input side, the picture is obtained by camera integration over a period of one field.
- The vertical lines are read from the camera with equal time intervals as indicated by the slope of the "field Input" bar in the figure.
- The timing of the display is similar to the input as shown in the figure.
- Coding of the top of the picture is started as soon as the two fields are ready at the top.
- Decoding is started as soon as it is guarantied that the bits representing the top of the picture have arrived.

With these assumptions, the following relations exist between the different types of delay:

TOTAL DELAY = SAMPLING DELAY + CODING/DECODING DELAY

CODING/DECODING DELAY = INTERLACE DELAY + BUFFER SIZE

SAMPLING DELAY (=T):
This delay is connected to the way the camera and monitor operates. In figure 14 the sampling delay is T. This delay is present also if the camera is connected directly to the monitor without any coding. It is not part of the coding /decoding delay.

INTERLACE DELAY (=2T)
Because the picture comes field by field from the camera - but is coded as a whole picture - a delay of 2T is introduced (see figure 14). This is called "interlace delay" because it is due to the interlace nature of the picture format.

We therefore end up with the following expression for coding/decoding delay with the present coding method:

CODING/DECODING DELAY = 2T + BUFFER SIZE

17.2. Delay for the coded sequences.

The table below shows the buffer sizes and resulting coding/decoding delays for 4 and 9 Mb/s coding.

Bitrate (Mb/s)	Buffer size	Coding/decoding delay (milliseconds)
4	130 milliseconds = 520 000 bits	170
9	120 milliseconds = 1 080 000 bits	160

17.3. Coding mode for reduced delay.

For conversational services there is a strong need to reduce the coding/decoding delay. On the other hand, features like fast forward/backward is of little interest for such applications.

In the table of delay above, the main contribution is seen to come from the buffersize. The need for the large buffersize is again dictated from the request for INTRA picture every 0.4 seconds.

A coding mode is therefore defined where one SLICE is coded INTRA for every picture. This means that the whole picture is updated once every 36 pictures - or once every 1.44 seconds. To guarantee that transmission errors etc. are corrected within 1.44 seconds, some additional constraints are put on the motion vectors. The limitation is effective in the SLICE above the one being coded INTRA. This is illustrated in figure 15 where predictions are always made from the area marked "new" and which guarantees the total refresh after 36 frames.

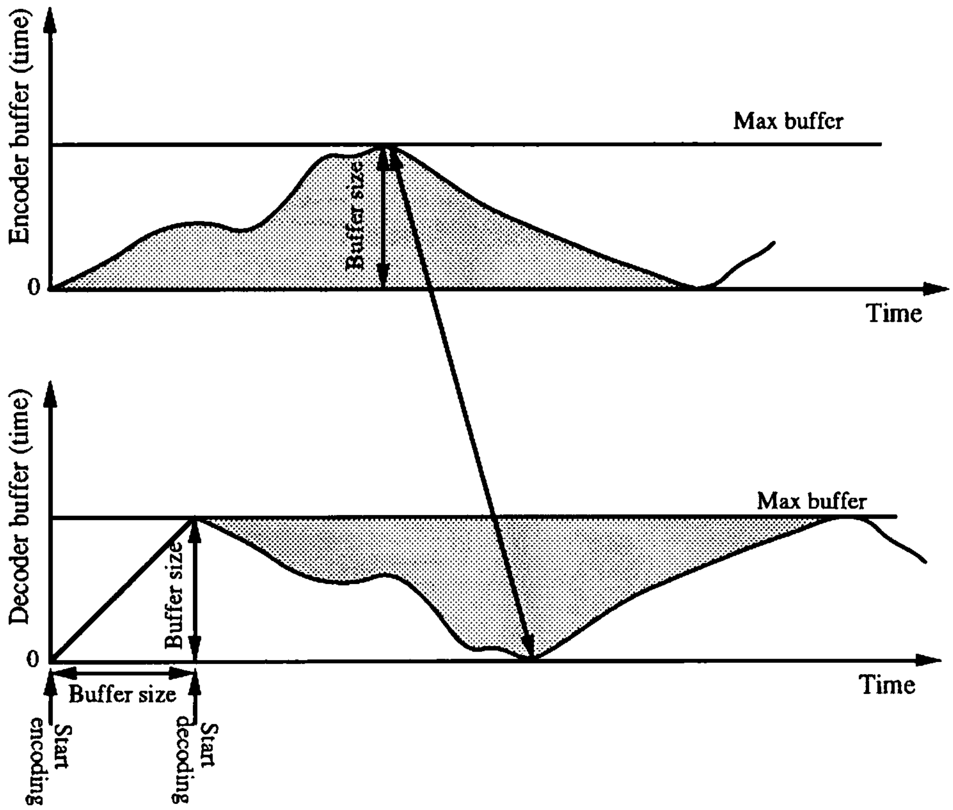


Figure 13. The filling of encoder and decoder buffers are shown. The buffer sizes are equal on both sides and is measured in time for emptying the full buffer. The figure shows that: Buffer delay = Buffer size.

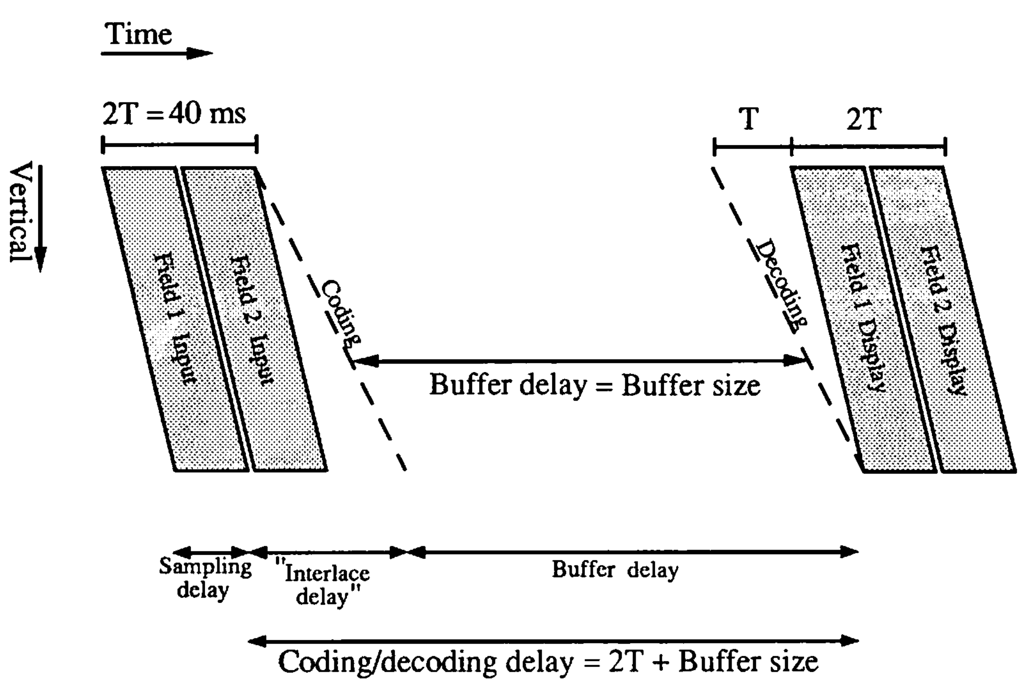


Figure 14. The figure shows the timing of input, coding, decoding and display of a picture. The buffer delay (see figure 13) and total delay are also shown.
T is the time between two fields (= 20 ms with 50 Hz field frequency).

In the table below, the corresponding buffersize and coding/decoding delay for 4 Mb/s are shown. The results for MOBCAL and FLOWERGARDEN are shown separately from TABLE TENNIS. The first two sequences contains no scene changes and may therefore be coded with very low delay. The scene changes in TABLE TENNIS requires larger buffer size for this sequence because the present coding method gives no special treatment to scene changes.

Sequences (with 4 Mb/s)	Buffer size	Coding/decoding delay (milliseconds)
MOBCAL+FLOWERGARDEN	35 milliseconds	75
TABLE TENNIS	75 "	115

The conclusions from the results in the table above is that very low coding delay is possible by the proposed coding method. To maintain low delay in situations with for instance abrupt motion or scene changes, special treatment must be given to those situations - such as frame dropping. In this case the analysis of coding/decoding delay must also be modified from what is shown in figures 13 and 14.

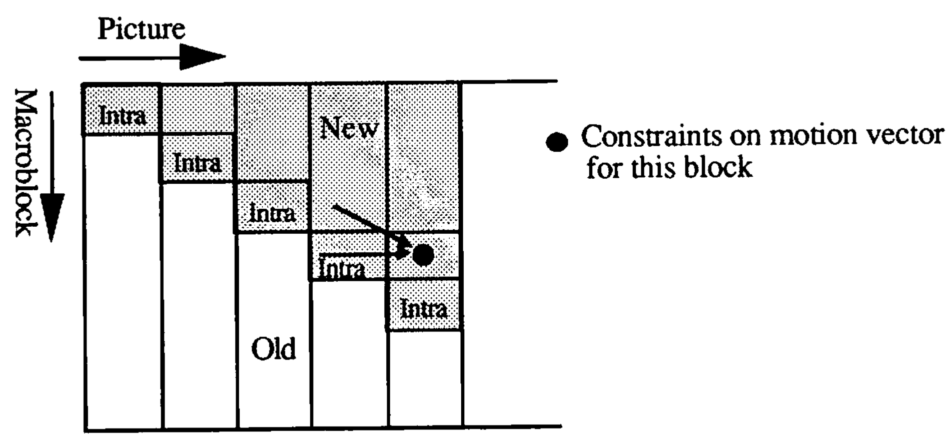


Figure 15. Coding for low delay. Illustration of macroblocks that are INTRA coded and macroblocks with constraints on motion vectors to ensure fast update.

18. Coding results/statistics.

The statistics from coding the 7 sequences are listed in Annex A. Explanations to some of the items in the tables that are not self explanatory are found below.

INTRA/INTER:
Statistics are given separately for the first frame in a GOP that is INTRA coded and the remaining 9 frames in the GOP that are INTER coded.

SNR Chrominance:
SNR for chrominance is given as an average over both of the chrominance components (U and V).

Av. Quantizer step:
The quantizer stepsize is averaged over all SLICEs in the sequence. Referring to Section 12.3, the contribution from MQUANT is not included. Referring to the same section, the definition of the average value is:

$$\text{Av. Quantizer step} = \left(\sum_{i=1}^{4500} QS(QUANT) \right) / 4500$$

Where QS(QUANT) is the quantizer stepsize for each of the 4500 SLICEs.

VLC:
One of the differences between this method and H.261/MPEG1 is the VLC tables for coefficient coding. This section is therefore included to show the use of these different VLCs. The numbers listed are the average number of times pr. block that a specific VLC (0,1,2) has been used to code coefficients and EOBs. The average number of zeros when a specific VLC was chosen is also given.

19. Conclusions.

A description of the "VADIS/COST Forward Predictive Coding" method has been given. There has been extensive use of graphics to make the method easily understandable. For more detailed definitions, FORTRAN syntax has been used whereever needed.

Statistics of the 7 coded sequences are listed in Annex A. Annex B shows a listing of the sizes of the different files representing bitstreams. The listing is in response to the DIR/SIZE command from VAX/VMS. The unit in the listing is 512 Bytes = 4096 bits.

Additional features that will be demonstrated on D1 tape:

- Fast forward with speed 2.5 times normal playback speed.
- Fast backward with speed 2.5 times normal playback speed.
- Three sequnces coded with 3 Mb/s to demonstrate compatibility by simulcast. A 1 Mb/s cannel is assumed for (H.261/MPEG1) for a total bitrate of 4 Mb/s.
- Low bitrate coding at 4 Mb/s. Possible coding/decoding of 75 milliseconds is demonstrated.

20. Annex A: Statistics of the coded sequences.

```
SEQUENCE             :TABLE TENNIS
NUMBER OF FRAMES     :         125
BITRATE/120          :     8999548
BITRATE/125          :     9082619
DATE                 :      910925
```

ITEM	ALL	INTRA	INTER	
SNR Luminance	34.50	34.99	34.45	
SNR Chrominance	40.00	40.39	39.96	
Av. Quantizer step	5.24	4.25	5.37	
COEFFS./ZEROS:				
No. of nonzero Y	7.59	16.52	6.55	1/bl
No. of zeros, Y	12.91	14.81	12.69	1/bl
No. of nonzero C	1.90	5.51	1.48	1/bl
No. of zeros, C	3.00	5.62	2.69	1/bl
VLC:				
VLC-0 coeffs.	0.89	0.53	0.93	1/bl
" zeros.	2.57	0.74	2.78	1/bl
" EOB.	0.73	0.39	0.77	1/bl
VLC-1 coeffs.	2.28	4.56	2.01	1/bl
" zeros.	4.42	6.61	4.16	1/bl
" EOB.	0.23	0.57	0.19	1/bl
VLC-2 coeffs.	1.58	5.92	1.07	1/bl
" zeros.	0.96	2.87	0.74	1/bl
" EOB.	0.01	0.04	0.01	1/bl
MBTYPE:				
INTER	1370	0	1529	1/fr
INTRA FRAME	195	1552	38	1/fr
" FIELD	10	67	4	1/fr
NO CODING	42	0	47	1/fr
BITS:				
MB-type+Startcodes	4245	4245	4245	1/fr
Vectors	7156	0	7987	1/fr
Coeffs Y	267466	656646	222293	1/fr
Coeffs C	65167	191254	50532	1/fr
EOB Y	11315	16723	10688	1/fr
EOB C	7954	13226	7342	1/fr
TOTAL	363305	882097	303088	1/fr

BITRATE/120 = Average bitrate over 12 full GOPs (120 frames).
BITRATE/125 = Average bitrate over all 125 frames.
/fr: Average over all frames (of that type).
/bl: Average over all 8*8 blocks with that frame type.

SEQUENCE : TABLE TENNIS (9 Mb/s)

Table showing SNR(in dB) and bitusage for each picture in a sequence.
SNR : Values under GOP show SNR for the whole GOP.
BITS: Values under GOP are accumulated number of bits after each GOP.

	GOP	INTRA	INTER 1	2	3	4	5	6	7	8	9
SNRY											
	30.62	29.93	30.41	31.64	31.60	32.65	30.17	27.95	29.36	31.80	33.48
	32.42	35.15	35.66	34.93	34.61	36.17	35.57	35.85	36.07	36.43	35.43
	33.35	36.36	36.36	36.65	35.80	36.88	36.13	36.47	36.03	36.59	35.00
	33.80	36.44	35.35	35.55	35.59	35.95	34.96	35.94	35.19	35.77	34.43
	34.06	36.13	34.67	35.45	35.34	35.62	35.03	35.91	35.14	35.90	34.59
	34.11	36.01	34.81	35.85	31.96	31.56	33.22	36.35	35.54	36.70	35.14
	34.33	35.93	34.94	36.78	35.36	36.52	35.94	36.89	35.69	36.54	35.46
	34.52	36.47	35.95	36.40	35.71	36.77	35.90	36.71	35.97	36.83	35.36
	34.44	36.75	35.53	31.99	31.13	31.51	34.15	35.60	35.17	36.10	35.17
	34.52	35.50	33.98	35.73	35.56	36.73	35.72	36.03	35.08	35.42	33.48
	34.52	35.38	35.24	34.53	33.58	34.79	34.59	34.69	34.19	35.17	33.67
	34.50	35.52	34.01	34.87	33.50	35.13	33.79	35.58	33.76	34.56	33.46
	0.00	35.25	33.94	35.09	33.63	34.79	0.00	0.00	0.00	0.00	0.00
SNRC											
	38.73	38.62	38.81	39.29	39.26	39.63	39.15	37.89	36.84	38.90	39.79
	39.72	41.25	41.26	40.94	40.68	41.36	40.99	40.95	40.95	41.12	40.52
	40.05	41.40	41.32	41.35	40.65	41.20	40.77	40.83	40.45	40.69	39.61
	39.99	40.65	40.08	39.99	39.96	40.15	39.41	39.88	39.46	39.75	39.00
	39.84	40.14	39.22	39.42	39.40	39.50	39.07	39.54	39.02	39.36	38.49
	39.74	39.54	38.85	39.45	37.69	37.56	38.76	40.74	40.38	40.94	40.32
	39.87	40.68	40.25	41.13	40.66	41.00	40.77	41.07	40.73	40.97	40.67
	40.00	41.03	40.81	41.04	40.78	41.22	40.92	41.20	41.01	41.27	40.83
	39.94	41.33	40.79	37.82	37.61	37.93	39.72	40.30	40.28	40.55	40.33
	39.99	40.27	39.87	40.81	40.67	41.09	40.80	40.81	40.52	40.46	39.93
	39.98	40.32	40.16	39.94	39.66	39.96	39.81	39.90	39.67	40.09	39.57
	40.00	40.49	39.99	40.20	39.87	40.32	39.99	40.64	40.19	40.40	39.86
	0.00	40.20	39.93	40.30	39.74	40.17	0.00	0.00	0.00	0.00	0.00
BITS											
	3670581	834746	287045	385258	255885	411304	296363	393655	125002	347633	333690
	7223582	743067	433380	273471	209829	453473	266958	314897	316488	368604	172834
	10799510	650501	336969	391522	227794	451386	281714	370235	290860	409081	165866
	14393475	767156	250453	314215	341002	398068	240817	413506	279308	386655	202785
	17989017	734744	223202	362846	343755	363350	270869	407715	281868	400730	206463
	21568630	729938	231838	427394	474008	47272	277999	543794	239024	471193	137153
	25195654	923541	192766	513854	152478	399232	259680	442763	197670	386007	159033
	28808874	1030179	284318	368158	196749	408978	190950	388275	214022	410671	120920
	32380568	1090549	222738	649536	24218	72457	398014	396033	203436	383876	130837
	36004788	1004594	49057	382664	261015	490660	263093	359883	281943	386263	145048
	39599687	1011440	348199	279258	227188	338788	274668	315688	225977	385152	188541
	43197833	990705	187176	392073	210369	434827	170595	454641	228371	364571	164818
	0	956089	237677	413158	217226	391115	0	0	0	0	0

SEQUENCE : FLOWERGARDEN
NUMBER OF FRAMES : 125
BITRATE/120 : 8978387
BITRATE/125 : 9119401
DATE : 910925

ITEM	ALL	INTRA	INTER	
SNR Luminance	31.91	32.03	31.90	
SNR Chrominance	35.14	35.12	35.15	
Av. Quantizer step	9.05	7.61	9.23	
COEFFS./ZEROS:				
No. of nonzero Y	7.98	14.82	7.19	1/bl
No. of zeros, Y	8.50	10.51	8.27	1/bl
No. of nonzero C	1.90	5.56	1.47	1/bl
No. of zeros, C	2.73	4.36	2.54	1/bl
VLC:				
VLC-0 coeffs.	0.61	0.45	0.62	1/bl
" zeros.	1.24	0.52	1.33	1/bl
" EOB.	0.70	0.43	0.73	1/bl
VLC-1 coeffs.	2.34	3.65	2.18	1/bl
" zeros.	3.44	4.72	3.30	1/bl
" EOB.	0.29	0.52	0.26	1/bl
VLC-2 coeffs.	1.99	6.08	1.52	1/bl
" zeros.	0.92	2.20	0.78	1/bl
" EOB.	0.01	0.04	0.01	1/bl
MBTYPE:				
INTER	1447	0	1615	1/fr
INTRA FRAME	161	1533	1	1/fr
" FIELD	9	86	0	1/fr
NO CODING	2	0	2	1/fr
BITS:				
MB-type+Startcodes	4245	4245	4245	1/fr
Vectors	9380	0	10469	1/fr
Coeffs Y	266915	591690	229218	1/fr
Coeffs C	63174	194957	47878	1/fr
EOB Y	12857	15850	12509	1/fr
EOB C	8204	12994	7648	1/fr
TOTAL	364777	819737	311969	1/fr

BITRATE/120 = Average bitrate over 12 full GOPs (120 frames).
BITRATE/125 = Average bitrate over all 125 frames.
/fr: Average over all frames (of that type).
/bl: Average over all 8*8 blocks with that frame type.

SEQUENCE : FLOWERGARDEN (9 Mb/s)

Table showing SNR(in dB) and bitusage for each picture in a sequence.
SNR : Values under GOP show SNR for the whole GOP.
BITS: Values under GOP are accumulated number of bits after each GOP.

	GOP	INTRA	INTER								
			1	2	3	4	5	6	7	8	9
SNRY											
	31.75	34.11	34.49	32.04	29.94	31.72	32.52	32.27	30.45	31.34	30.74
	32.25	29.94	30.38	33.63	33.24	35.02	33.61	34.58	34.26	34.55	32.55
	32.34	34.38	34.22	34.07	32.21	32.80	32.28	34.12	32.11	30.85	30.42
	32.44	34.00	31.88	30.90	31.41	33.75	33.43	33.83	33.64	34.29	32.07
	32.27	33.57	31.64	32.01	31.49	32.99	31.22	31.33	31.12	31.80	30.30
	32.17	31.87	31.47	33.20	30.53	31.50	32.61	32.41	30.98	32.66	30.49
	32.30	30.41	31.43	34.20	33.44	35.04	33.56	34.04	33.38	35.81	33.53
	32.32	34.23	34.17	33.34	33.65	35.04	33.13	31.93	30.36	31.48	30.25
	32.17	30.20	31.52	33.36	30.55	30.13	30.90	32.49	31.90	32.53	29.27
	32.03	32.44	31.60	30.56	29.91	32.02	30.51	30.56	31.04	32.80	28.99
	31.91	30.75	30.39	33.02	31.01	30.82	30.81	31.79	30.16	31.16	29.96
	31.90	30.40	30.95	31.05	30.58	32.88	32.30	34.28	32.91	32.24	31.37
	0.00	34.87	32.45	30.22	30.81	35.36	0.00	0.00	0.00	0.00	0.00
SNRC											
	35.35	36.22	36.33	35.33	34.68	35.37	35.61	35.47	34.79	35.13	34.92
	35.52	34.33	34.57	35.94	35.82	36.35	35.97	36.35	36.15	36.28	35.63
	35.53	36.18	36.20	36.08	35.45	35.54	35.46	36.06	35.28	34.83	34.76
	35.57	36.33	35.60	35.08	35.14	36.02	35.86	35.82	35.86	35.98	35.52
	35.45	35.78	35.22	35.14	34.85	35.29	34.73	34.80	34.70	34.98	34.57
	35.36	34.83	34.77	35.30	34.56	34.96	35.31	35.17	34.73	35.33	34.65
	35.38	34.33	34.78	35.77	35.55	36.10	35.66	35.56	35.43	36.39	35.88
	35.36	35.66	35.67	35.39	35.57	35.95	35.54	35.12	34.51	34.88	34.31
	35.29	34.12	34.76	35.43	34.50	34.33	34.65	35.10	35.00	35.13	34.33
	35.22	35.08	34.85	34.48	34.37	35.04	34.56	34.54	34.82	35.19	34.22
	35.16	34.26	34.19	35.24	34.59	34.53	34.59	34.91	34.46	34.76	34.34
	35.14	34.32	34.53	34.52	34.37	35.21	35.01	35.62	35.29	35.05	34.82
	0.00	36.13	35.32	34.53	34.81	36.10	0.00	0.00	0.00	0.00	0.00
BITS											
	3640678	841932	422969	302801	179346	358424	364091	378528	219417	322481	250689
	7201230	536930	246669	501433	234980	470612	244260	385641	330074	388987	220966
	10691528	967812	341179	316686	231365	357182	195974	421280	309696	220438	128686
	14392093	985624	233064	258408	302804	438904	295507	321771	309427	446296	108760
	17973395	917611	206280	353919	294004	424860	267343	304294	336491	405646	70854
	21681402	775234	199555	548837	197159	323758	421247	386495	220653	479451	155618
	25212718	652676	262303	494717	189671	492298	184435	411205	197693	528190	118128
	28878717	1029958	371598	204440	272475	426812	236062	341220	204299	350976	228159
	32377752	637610	315764	485558	232824	235492	323162	384714	265392	458057	160462
	36013465	846196	360324	267251	233392	453297	276068	260153	298843	515205	124984
	39622693	686480	222152	517819	267272	297741	331557	433295	243677	361172	248063
	43096260	669784	374626	324902	246020	455723	201908	453777	295987	302069	148771
	0	1108732	309689	176509	187614	718203	0	0	0	0	0

SEQUENCE : POPPLE
NUMBER OF FRAMES : 125
BITRATE/120 : 8993732
BITRATE/125 : 9016635
DATE : 910925

ITEM	ALL	INTRA	INTER	
SNR Luminance	32.85	33.99	32.74	
SNR Chrominance	34.86	36.36	34.71	
Av. Quantizer step	7.53	6.23	7.70	
COEFFS./ZEROS:				
No. of nonzero Y	5.73	8.97	5.35	1/bl
No. of zeros, Y	8.92	10.12	8.78	1/bl
No. of nonzero C	2.69	4.24	2.51	1/bl
No. of zeros, C	4.63	5.75	4.50	1/bl
VLC:				
VLC-0 coeffs.	0.71	0.70	0.71	1/bl
" zeros.	1.89	1.66	1.92	1/bl
" EOB.	0.77	0.64	0.78	1/bl
VLC-1 coeffs.	1.75	2.34	1.69	1/bl
" zeros.	3.41	3.89	3.35	1/bl
" EOB.	0.21	0.32	0.19	1/bl
VLC-2 coeffs.	1.75	3.57	1.54	1/bl
" zeros.	1.48	2.39	1.37	1/bl
" EOB.	0.02	0.05	0.02	1/bl
MBTYPE:				
INTER	1403	0	1566	1/fr
INTRA FRAME	185	1499	33	1/fr
" FIELD	22	120	11	1/fr
NO CODING	8	0	9	1/fr
BITS:				
MB-type+Startcodes	4245	4245	4245	1/fr
Vectors	19282	0	21520	1/fr
Coeffs Y	210647	372312	191882	1/fr
Coeffs C	107036	176694	98950	1/fr
EOB Y	10272	12024	10069	1/fr
EOB C	9182	11536	8909	1/fr
TOTAL	360666	576813	335577	1/fr

BITRATE/120 = Average bitrate over 12 full GOPs (120 frames).
BITRATE/125 = Average bitrate over all 125 frames.
/fr: Average over all frames (of that type).
/bl: Average over all 8*8 blocks with that frame type.

SEQUENCE : POPPLE (9 Mb/s)

Table showing SNR(in dB) and bitusage for each picture in a sequence.
SNR : Values under GOP show SNR for the whole GOP.
BITS: Values under GOP are accumulated number of bits after each GOP.

	GOP	INTRA	INTER								
			1	2	3	4	5	6	7	8	9
SNRY											
	34.91	35.66	35.08	35.31	34.29	35.85	34.54	34.66	35.02	35.59	33.62
	34.84	34.60	34.70	35.39	33.93	35.69	34.62	35.06	34.83	35.55	33.84
	34.79	35.30	34.47	34.95	34.15	35.42	34.08	35.49	34.53	35.04	33.89
	34.79	35.64	34.64	35.27	34.30	35.49	34.47	35.30	34.45	35.34	33.48
	34.51	35.04	33.87	35.41	33.60	33.65	33.02	34.65	32.94	34.05	30.86
	34.31	33.27	33.47	33.96	32.82	34.14	33.08	33.40	33.21	34.43	32.96
	34.44	36.23	35.55	35.27	34.01	36.07	35.42	35.61	34.88	36.42	34.28
	34.54	36.05	35.30	36.34	34.77	35.67	35.16	35.66	34.37	35.65	34.40
	34.44	35.66	34.61	35.52	33.79	34.10	33.64	34.39	32.39	33.36	31.68
	33.97	33.46	30.83	31.94	32.88	32.69	29.85	31.45	31.57	31.15	28.20
	33.42	32.00	30.07	29.88	29.43	30.85	29.55	30.21	29.89	30.95	28.31
	33.00	32.05	29.63	30.30	30.38	30.85	28.82	30.23	30.17	30.27	28.04
	0.00	31.26	29.84	30.49	29.65	30.44	0.00	0.00	0.00	0.00	0.00
SNRC											
	39.31	39.83	39.48	39.77	38.89	39.79	39.26	38.91	39.32	39.82	38.31
	39.30	39.46	38.98	39.94	38.59	39.71	39.27	39.38	39.31	39.88	38.57
	39.32	40.03	39.17	39.64	38.94	39.81	39.12	39.57	39.31	39.36	38.82
	39.35	39.95	39.45	39.68	39.15	39.98	39.28	39.74	39.15	39.81	38.61
	39.29	39.81	38.86	39.96	39.23	39.03	38.62	39.32	38.74	39.06	37.95
	39.12	38.71	38.76	39.23	38.37	39.08	38.37	38.35	37.67	38.56	37.28
	39.07	39.90	39.31	39.01	37.87	39.34	38.84	38.90	38.10	39.63	37.32
	38.90	39.40	38.35	39.32	37.73	38.39	37.93	37.85	36.87	37.63	36.33
	38.24	37.52	36.23	37.15	35.11	35.62	34.56	35.15	33.53	33.92	32.88
	37.03	34.11	32.31	32.70	33.30	32.89	30.94	31.98	31.90	31.94	29.61
	35.86	32.91	30.89	30.52	30.31	31.03	30.07	30.33	30.28	31.25	29.29
	35.13	33.11	30.57	30.98	31.04	31.14	30.15	30.73	30.84	30.94	29.40
	0.00	32.46	30.58	30.80	30.54	30.65	0.00	0.00	0.00	0.00	0.00
BITS											
	3651484	751650	347188	386144	242718	443093	267245	299610	329836	404221	179779
	7204542	628937	322218	430301	214582	431326	278073	334223	309301	404687	199410
	10786495	738089	300630	368102	267167	419763	244148	408859	274934	341729	218532
	14412680	747612	296771	370578	264242	412204	277133	373852	285362	398991	199440
	18054445	679385	250424	446444	287863	335731	284937	424071	270396	444604	217910
	21540326	511975	348859	387090	270538	397718	306266	325787	308390	392700	236558
	25230880	635289	383235	364340	243636	432558	335304	355590	276716	435610	228276
	28813704	476509	326104	435439	275554	382095	331991	400378	280223	388296	286235
	32368629	444275	322266	442047	289236	358074	349027	412866	292182	370893	274059
	35926264	454501	231031	381063	400882	447573	237302	373215	437053	378017	216998
	39565587	480666	336951	360505	296936	473418	296262	369460	345682	434898	244545
	43169916	489837	305796	353621	352561	464298	248324	398063	387488	380602	223739
	0	459831	328456	408970	302615	413388	0	0	0	0	0

SEQUENCE :MOBILE&CALENDER
NUMBER OF FRAMES : 125
BITRATE/120 : 8996566
BITRATE/125 : 9080503
DATE : 910923

ITEM	ALL	INTRA	INTER	
SNR Luminance	30.59	31.05	30.54	
SNR Chrominance	36.45	36.62	36.43	
Av. Quantizer step	8.45	7.05	8.63	
COEFFS./ZEROS:				
No. of nonzero Y	7.49	16.54	6.44	/bl
No. of zeros, Y	11.11	12.31	10.97	/bl
No. of nonzero C	2.05	6.42	1.54	/bl
No. of zeros, C	3.07	4.63	2.89	/bl
VLC:				
VLC-0 coeffs.	0.96	0.51	1.02	/bl
" zeros.	2.31	0.64	2.51	/bl
" EOB.	0.73	0.31	0.77	/bl
VLC-1 coeffs.	2.16	4.36	1.91	/bl
" zeros.	3.76	5.19	3.59	/bl
" EOB.	0.26	0.64	0.21	/bl
VLC-2 coeffs.	1.64	6.62	1.07	/bl
" zeros.	1.02	2.64	0.83	/bl
" EOB.	0.02	0.05	0.01	/bl
MBTYPE:				
INTER	1445	0	1613	/fr
INTRA FRAME	168	1609	1	/fr
" FIELD	1	10	0	/fr
NO CODING	4	0	5	/fr
BITS:				
MB-type+Startcodes	4245	4245	4245	/fr
Vectors	6171	0	6888	/fr
Coeffs Y	261312	642500	217067	/fr
Coeffs C	71143	235438	52073	/fr
EOB Y	11996	17146	11399	/fr
EOB C	8351	15056	7573	/fr
TOTAL	363221	914386	299246	/fr

BITRATE/120 = Average bitrate over 12 full GOPs (120 frames).
BITRATE/125 = Average bitrate over all 125 frames.
/fr: Average over all frames (of that type).
/bl: Average over all 8*8 blocks with that frame type.

SEQUENCE : MOBILE&CALENDER (9 Mb/s)

Table showing SNR(in dB) and bitusage for each picture in a sequence.
SNR : Values under GOP show SNR for the whole GOP.
BITS: Values under GOP are accumulated number of bits after each GOP.

GOP	INTRA	INTER								
		1	2	3	4	5	6	7	8	9
SNRY										
29.63	31.13	30.90	30.75	29.34	30.15	28.93	29.53	28.55	29.53	28.45
30.12	29.59	29.03	31.29	30.65	31.79	30.97	31.98	31.12	31.91	29.60
30.49	31.33	30.97	31.55	30.59	31.87	31.00	32.25	31.49	32.29	30.47
30.73	32.39	31.28	31.85	31.57	32.31	30.52	31.77	31.19	31.94	30.86
30.83	32.44	31.59	32.62	31.56	31.98	30.94	31.66	30.60	31.20	29.05
30.56	30.36	30.16	30.74	28.84	28.91	28.60	29.24	28.71	29.90	29.35
30.52	31.15	29.66	31.38	30.93	30.32	29.86	31.08	30.01	30.85	28.73
30.49	30.16	30.07	30.89	29.74	31.00	30.15	30.87	30.16	30.62	29.25
30.50	30.57	29.93	31.09	30.47	31.22	30.03	30.88	30.04	31.48	30.01
30.58	31.69	30.98	32.06	31.50	32.25	31.80	32.53	30.98	31.72	29.63
30.56	31.13	30.90	30.03	29.83	30.88	30.03	30.75	29.99	30.66	29.55
30.57	31.52	30.05	31.12	30.81	31.16	30.20	31.29	30.43	31.21	29.76
0.00	31.13	30.00	31.71	30.88	31.52	0.00	0.00	0.00	0.00	0.00
SNRC										
36.36	37.04	36.99	36.88	36.29	36.70	36.07	36.35	35.74	36.16	35.64
36.50	36.13	36.05	36.81	36.60	37.00	36.74	37.11	36.82	37.02	36.28
36.60	36.57	36.55	36.71	36.49	37.05	36.76	37.20	36.98	37.18	36.63
36.70	37.06	36.86	37.10	37.04	37.31	36.70	37.20	36.92	37.29	36.70
36.74	37.42	37.02	37.59	37.20	37.35	36.92	37.07	36.61	36.74	35.76
36.56	36.36	36.33	36.44	35.58	35.53	35.27	35.50	35.25	35.87	35.61
36.51	36.38	35.94	36.74	36.53	36.32	36.02	36.43	35.99	36.31	35.49
36.46	36.12	36.18	36.43	35.90	36.38	36.06	36.37	36.11	36.28	35.65
36.45	36.34	36.12	36.60	36.32	36.63	36.20	36.57	36.11	36.88	36.08
36.49	37.04	36.66	37.28	36.92	37.37	36.98	37.30	36.60	36.78	35.88
36.46	36.81	36.68	36.20	35.86	36.39	35.96	36.30	35.90	36.16	35.59
36.45	36.51	36.01	36.42	36.26	36.46	36.14	36.63	36.26	36.55	35.91
0.00	36.46	36.09	36.72	36.34	36.55	0.00	0.00	0.00	0.00	0.00
BITS										
3627156	909601	348321	358747	216724	399898	234012	379403	228271	372881	179298
7218692	745336	230557	450408	237117	399687	271047	402334	242742	414935	197373
10779974	913219	306583	340802	220521	403048	206320	387165	243764	370633	169227
14369026	1040220	225294	344473	255827	388189	209338	384555	242057	368790	130309
18043645	1048015	139474	425324	262813	373732	249625	374743	253671	379050	168172
21542103	816358	286324	393253	228694	333297	284675	362369	238301	375890	179297
25216258	894443	143113	471599	325651	326668	279180	419512	259318	420736	133935
28806399	814925	281334	400159	227728	413810	237194	384710	282666	367628	179987
32371083	874819	247545	381861	258216	391461	235664	392950	208509	442221	131438
36016918	978574	188341	419039	245897	385274	234810	418418	223963	400083	151436
39568085	939574	321320	266217	250912	392136	230748	379111	234259	366238	170652
43183521	964944	146451	409514	305702	355321	244419	406582	259900	395152	127451
0	946987	201051	433571	230224	407161	0	0	0	0	0

SEQUENCE	:TABLE TENNIS
NUMBER OF FRAMES	: 125
BITRATE/120	: 3998247
BITRATE/125	: 4044833
DATE	: 910923

ITEM	ALL	INTRA	INTER	
SNR Luminance	31.33	31.56	31.30	
SNR Chrominance	37.92	38.12	37.89	
Av. Quantizer step	11.55	9.55	11.81	
COEFFS./ZEROS:				
No. of nonzero Y	3.17	9.49	2.43	1/bl
No. of zeros, Y	6.17	10.60	5.65	1/bl
No. of nonzero C	0.65	2.27	0.46	1/bl
No. of zeros, C	1.01	2.32	0.85	1/bl
VLC:				
VLC-0 coeffs.	0.61	0.67	0.60	1/bl
" zeros.	1.76	0.87	1.87	1/bl
" EOB.	0.80	0.61	0.82	1/bl
VLC-1 coeffs.	0.75	2.46	0.55	1/bl
" zeros.	1.43	3.87	1.15	1/bl
" EOB.	0.10	0.36	0.07	1/bl
VLC-2 coeffs.	0.55	2.76	0.29	1/bl
" zeros.	0.39	1.72	0.24	1/bl
" EOB.	0.01	0.03	0.00	1/bl
MBTYPE:				
INTER	1257	0	1403	1/fr
INTRA FRAME	195	1552	38	1/fr
" FIELD	10	67	4	1/fr
NO CODING	155	0	173	1/fr
BITS:				
MB-type+Startcodes	4245	4245	4245	1/fr
Vectors	7113	0	7938	1/fr
Coeffs Y	113313	354538	85314	1/fr
Coeffs C	22386	79642	15740	1/fr
EOB Y	8355	14754	7613	1/fr
EOB C	6380	9233	6049	1/fr
TOTAL	161794	462414	126900	1/fr

BITRATE/120 = Average bitrate over 12 full GOPs (120 frames).
BITRATE/125 = Average bitrate over all 125 frames.
/fr: Average over all frames (of that type).
/bl: Average over all 8*8 blocks with that frame type.

SEQUENCE : TABLE TENNIS (4 Mb/s)

Table showing SNR(in dB) and bitusage for each picture in a sequence.
SNR : Values under GOP show SNR for the whole GOP.
BITS: Values under GOP are accumulated number of bits after each GOP.

GOP	INTRA	INTER 1	2	3	4	5	6	7	8	9
SNRY										
27.26	26.22	26.16	27.00	27.08	27.54	26.84	25.73	28.09	29.33	30.85
29.30	32.60	33.14	32.85	32.84	33.72	33.13	33.82	33.81	34.15	33.22
30.34	33.83	33.93	34.16	33.40	34.19	33.59	34.12	33.56	34.10	32.69
30.86	33.43	32.88	33.19	33.13	33.21	32.63	33.29	32.60	33.02	32.13
31.16	33.22	32.18	33.06	32.41	32.72	32.56	32.99	32.21	32.88	31.86
31.11	32.84	32.11	32.97	28.34	28.51	29.16	32.02	31.52	33.17	32.30
31.32	31.78	31.69	32.82	32.38	33.67	32.94	33.69	33.40	33.81	33.23
31.56	33.72	32.90	33.80	33.45	33.89	33.66	33.98	33.69	34.00	33.46
31.36	33.89	32.82	28.13	27.92	28.04	29.41	30.57	31.03	31.39	31.31
31.41	31.56	30.95	31.86	32.06	33.15	32.43	32.92	32.44	32.02	30.65
31.39	32.05	31.22	31.27	31.18	31.38	30.94	31.30	31.16	31.22	30.54
31.34	31.13	30.67	31.32	29.91	31.17	30.65	31.83	30.41	30.89	30.27
0.00	31.57	30.89	31.47	30.35	31.27	0.00	0.00	0.00	0.00	0.00
SNRC										
36.93	36.90	36.92	37.38	37.33	37.63	37.49	36.63	35.24	36.56	37.83
37.97	39.60	39.63	39.41	39.31	39.68	39.20	39.40	39.08	39.32	38.75
38.22	39.45	39.37	39.47	38.70	39.19	38.69	38.92	38.37	38.59	37.55
38.04	37.92	37.61	37.71	37.74	37.74	37.37	37.65	37.27	37.41	36.93
37.78	37.56	37.00	37.31	36.90	36.97	36.88	36.93	36.53	36.72	36.20
37.60	36.70	36.41	36.91	35.42	35.62	36.09	37.72	37.53	38.62	38.18
37.74	37.84	37.95	38.54	38.35	39.11	38.81	39.10	39.00	39.18	38.97
37.90	39.10	38.69	39.30	39.18	39.39	39.32	39.46	39.36	39.47	39.23
37.81	39.34	38.92	35.70	35.65	35.85	36.93	37.41	37.84	37.95	37.96
37.88	37.96	37.80	38.49	38.62	39.05	38.86	38.97	38.78	38.61	38.22
37.89	38.30	38.00	37.94	37.91	37.94	37.84	38.01	37.92	37.97	37.76
37.91	37.88	37.95	38.10	37.82	38.28	38.17	38.55	38.26	38.37	38.16
0.00	38.19	38.09	38.26	37.95	38.23	0.00	0.00	0.00	0.00	0.00
BITS										
1607609	442843	67856	196148	99842	162154	154632	177519	59398	106934	140283
3208619	388591	194976	108162	103636	198148	86160	160603	125934	170395	64405
4802617	329302	146181	178255	89901	198545	102327	182673	106261	195261	65292
6403917	361433	102345	154858	146014	160213	116582	184393	110463	167481	97518
7994035	365681	96349	184905	122832	151503	134573	166288	110692	168204	89091
9595593	362611	103480	189428	217462	38287	73467	256687	57284	258519	44333
11156218	417397	107246	190122	67698	231704	55752	176037	97221	166903	50545
12736713	618078	46504	192350	74265	148098	80682	148409	77343	144133	50633
14360422	645796	47139	292847	21610	34185	147656	143177	124310	114289	52700
15996526	515913	19614	182893	117028	221452	55840	173317	142835	147384	59828
17603211	571420	75088	135732	121479	128729	102322	142096	108126	131815	89878
19191588	475289	102674	179769	58550	188046	89055	182035	93139	138516	81304
0	517023	99413	167541	87495	161109	0	0	0	0	0

```
SEQUENCE            :FLOWERGARDEN
NUMBER OF FRAMES    :          125
BITRATE/120         :      3994083
BITRATE/125         :      4049665
DATE                :       910923
```

ITEM	ALL	INTRA	INTER	
SNR Luminance	27.74	27.81	27.73	
SNR Chrominance	33.20	33.11	33.21	
Av. Quantizer step	22.87	19.06	23.36	
COEFFS./ZEROS:				
No. of nonzero Y	3.39	8.56	2.79	1/bl
No. of zeros, Y	4.67	7.09	4.39	1/bl
No. of nonzero C	0.59	2.56	0.37	1/bl
No. of zeros, C	0.76	1.68	0.65	1/bl
VLC:				
VLC-0 coeffs.	0.53	0.49	0.53	1/bl
" zeros.	1.07	0.45	1.14	1/bl
" EOB.	0.85	0.55	0.89	1/bl
VLC-1 coeffs.	0.91	2.25	0.75	1/bl
" zeros.	1.32	2.67	1.17	1/bl
" EOB.	0.14	0.42	0.11	1/bl
VLC-2 coeffs.	0.56	2.82	0.29	1/bl
" zeros.	0.32	1.26	0.21	1/bl
" EOB.	0.01	0.04	0.00	1/bl
MBTYPE:				
INTER	1447	0	1615	1/fr
INTRA FRAME	161	1533	1	1/fr
" FIELD	9	86	0	1/fr
NO CODING	2	0	2	1/fr
BITS:				
MB-type+Startcodes	4245	4245	4245	1/fr
Vectors	9660	0	10781	1/fr
Coeffs Y	111385	305048	88906	1/fr
Coeffs C	19799	84347	12307	1/fr
EOB Y	9873	14860	9294	1/fr
EOB C	7023	10765	6588	1/fr
TOTAL	161987	419266	132124	1/fr

BITRATE/120 = Average bitrate over 12 full GOPs (120 frames).
BITRATE/125 = Average bitrate over all 125 frames.
/fr: Average over all frames (of that type).
/bl: Average over all 8*8 blocks with that frame type.

SEQUENCE : FLOWERGARDEN (4 Mb/s)

Table showing SNR(in dB) and bitusage for each picture in a sequence.
SNR : Values under GOP show SNR for the whole GOP.
BITS: Values under GOP are accumulated number of bits after each GOP.

GOP	INTRA	INTER 1	2	3	4	5	6	7	8	9
SNRY										
27.76	28.60	29.48	27.85	26.54	28.23	27.71	28.27	27.15	27.60	26.93
28.12	26.78	27.36	28.28	28.36	29.75	28.54	29.98	29.15	30.03	28.20
28.15	28.79	28.68	29.31	28.21	28.23	28.24	29.67	27.40	27.09	27.28
28.21	28.98	27.93	27.65	27.31	28.75	28.41	29.08	28.93	28.97	28.14
28.07	29.23	27.41	27.68	27.76	28.06	27.30	27.51	27.38	27.22	26.68
27.99	28.07	27.46	28.57	26.61	27.54	27.76	27.98	27.20	28.46	26.53
28.08	26.77	27.59	28.29	28.78	29.33	28.63	30.20	29.03	29.70	29.70
28.08	28.25	28.61	28.43	29.09	29.39	28.78	28.45	26.51	27.49	26.59
27.98	27.57	28.20	28.43	27.07	27.01	26.87	27.65	27.69	27.71	25.51
27.87	28.05	26.81	26.70	27.06	27.47	26.02	27.37	27.28	28.01	25.81
27.77	26.57	26.62	27.88	26.28	27.26	27.08	27.10	26.55	27.65	25.68
27.73	26.55	26.59	26.64	26.75	27.83	27.48	29.86	27.68	27.65	27.80
0.00	28.65	27.12	26.94	27.66	29.15	0.00	0.00	0.00	0.00	0.00
SNRC										
33.36	33.69	34.07	33.45	33.01	33.55	33.28	33.51	33.05	33.19	32.91
33.49	32.57	33.03	33.46	33.56	34.08	33.74	34.26	33.95	34.26	33.72
33.50	33.69	33.69	33.89	33.59	33.47	33.47	34.00	33.30	33.10	33.17
33.54	33.88	33.53	33.39	33.22	33.77	33.62	33.85	33.86	33.77	33.50
33.45	33.86	33.47	33.43	33.25	33.27	32.91	33.01	32.87	32.73	32.56
33.39	33.11	32.99	33.36	32.86	33.11	33.12	33.20	32.92	33.39	32.92
33.39	32.43	32.97	33.33	33.51	33.63	33.48	33.70	33.41	33.76	33.72
33.36	33.18	33.33	33.27	33.55	33.60	33.48	33.33	32.75	33.05	32.70
33.32	32.94	33.25	33.37	32.99	32.86	32.76	33.02	33.07	33.07	32.63
33.28	33.21	32.87	32.80	32.90	33.01	32.56	32.98	32.98	33.21	32.66
33.22	32.42	32.54	33.02	32.56	32.91	32.78	32.80	32.62	33.02	32.53
33.20	32.46	32.60	32.66	32.75	33.15	33.03	33.70	33.27	33.12	33.09
0.00	33.37	32.96	32.84	33.09	33.46	0.00	0.00	0.00	0.00	0.00
BITS										
1611310	381756	210803	126545	76444	186759	109205	177371	103905	144012	94510
3203089	294935	144222	170572	103809	230052	67801	210293	96914	198822	74359
4769321	459298	107816	167984	106659	147006	84612	220262	94942	100035	77618
6377286	481240	97309	140254	106316	180043	100377	166122	118025	168392	49887
7975538	509047	58494	145997	144432	155517	122424	133283	151560	135509	41989
9627819	440136	62441	251451	65344	151247	145289	174545	92181	230308	39339
11220354	343642	135304	154245	132458	189851	63283	271991	40775	148095	112891
12807369	474593	149765	90850	141294	141430	107697	189522	56352	151632	83880
14381931	414212	148543	156998	111527	121455	117446	146391	128071	178240	51679
16009955	447648	113747	112982	141382	185924	79245	172703	110304	213947	50142
17608874	350086	110386	217770	83769	162882	146961	152106	109135	201525	64299
19171599	354068	149170	129339	130352	186009	69219	280347	55215	121789	87217
0	499785	89283	114702	112016	260944	0	0	0	0	0

SEQUENCE : MOBILE&CALENDER
NUMBER OF FRAMES : 125
BITRATE/120 : 3998802
BITRATE/125 : 4048435
DATE : 910923

ITEM	ALL	INTRA	INTER	
SNR Luminance	26.82	26.65	26.84	
SNR Chrominance	34.20	34.09	34.22	
Av. Quantizer step	21.03	17.54	21.48	
COEFFS./ZEROS:				
No. of nonzero Y	3.11	9.06	2.41	1/bl
No. of zeros, Y	5.63	8.86	5.25	1/bl
No. of nonzero C	0.75	3.17	0.46	1/bl
No. of zeros, C	0.99	2.13	0.86	1/bl
VLC:				
VLC-0 coeffs.	0.66	0.64	0.66	1/bl
" zeros.	1.63	0.70	1.73	1/bl
" EOB.	0.87	0.47	0.91	1/bl
VLC-1 coeffs.	0.75	2.45	0.55	1/bl
" zeros.	1.30	3.04	1.10	1/bl
" EOB.	0.12	0.47	0.08	1/bl
VLC-2 coeffs.	0.52	3.03	0.23	1/bl
" zeros.	0.39	1.76	0.23	1/bl
" EOB.	0.01	0.06	0.00	1/bl
MBTYPE:				
INTER	1442	0	1609	1/fr
INTRA FRAME	168	1609	1	1/fr
" FIELD	1	10	0	1/fr
NO CODING	7	0	8	1/fr
BITS:				
MB-type+Startcodes	4245	4245	4245	1/fr
Vectors	6531	0	7289	1/fr
Coeffs Y	109056	329740	83441	1/fr
Coeffs C	25672	111671	15690	1/fr
EOB Y	9233	16139	8431	1/fr
EOB C	7199	11992	6643	1/fr
TOTAL	161938	473787	125741	1/fr

BITRATE/120 = Average bitrate over 12 full GOPs (120 frames).
BITRATE/125 = Average bitrate over all 125 frames.
/fr: Average over all frames (of that type).
/bl: Average over all 8*8 blocks with that frame type.

SEQUENCE : MOBILE&CALENDER (4 Mb/s)

Table showing SNR(in dB) and bitusage for each picture in a sequence.
SNR : Values under GOP show SNR for the whole GOP.
BITS: Values under GOP are accumulated number of bits after each GOP.

GOP	INTRA					INTER				
		1	2	3	4	5	6	7	8	9
SNRY										
26.19	26.56	26.37	27.00	26.10	26.61	26.13	26.26	25.65	26.14	25.33
26.43	26.47	26.46	26.71	26.56	27.04	26.67	27.17	26.89	27.05	25.90
26.68	26.91	27.21	27.15	26.78	27.48	27.00	27.67	27.36	27.82	27.06
26.88	26.89	28.31	27.87	27.25	28.08	27.47	27.62	27.42	27.74	27.23
27.00	26.79	28.83	28.20	27.12	27.91	28.13	28.17	26.99	27.40	26.12
26.80	26.79	27.74	26.51	25.44	25.65	25.23	25.81	25.18	25.90	25.44
26.75	26.40	26.72	27.23	26.18	26.94	26.56	26.68	26.14	26.43	25.40
26.72	25.97	27.43	26.58	26.18	27.13	26.54	26.69	26.41	26.69	25.91
26.74	26.66	27.04	27.34	26.59	27.38	27.00	27.26	26.51	27.24	26.36
26.80	26.80	27.77	27.71	27.16	27.97	27.68	27.74	27.07	27.25	26.39
26.79	26.87	27.82	27.03	26.28	26.84	26.73	26.93	26.26	26.72	25.92
26.81	26.62	27.15	27.12	26.43	27.29	27.28	27.50	26.77	27.23	26.80
0.00	26.80	27.17	27.38	26.77	27.47	0.00	0.00	0.00	0.00	0.00
SNRC										
34.14	34.33	34.39	34.69	34.19	34.42	34.09	34.15	33.70	34.00	33.52
34.30	34.35	34.44	34.55	34.40	34.63	34.44	34.71	34.56	34.64	34.09
34.43	34.56	34.68	34.63	34.47	34.83	34.62	34.90	34.77	34.90	34.49
34.51	34.33	35.11	34.90	34.63	35.12	34.81	34.85	34.65	34.85	34.44
34.55	34.20	35.62	35.30	34.63	34.98	34.99	35.02	34.40	34.53	33.78
34.38	34.34	34.91	34.26	33.48	33.61	33.17	33.43	32.97	33.45	33.07
34.31	33.71	34.13	34.41	33.92	34.23	33.97	34.02	33.73	33.84	33.27
34.26	33.56	34.49	34.05	33.70	34.29	33.97	34.05	33.84	33.94	33.42
34.24	34.03	34.35	34.42	33.91	34.31	34.06	34.24	33.74	34.25	33.64
34.25	34.01	34.82	34.72	34.21	34.83	34.54	34.59	34.15	34.19	33.58
34.22	34.15	34.82	34.39	33.75	34.01	33.87	33.97	33.51	33.85	33.30
34.21	33.81	34.29	34.23	33.75	34.20	34.21	34.36	33.87	34.06	33.68
0.00	33.86	34.37	34.41	33.91	34.27	0.00	0.00	0.00	0.00	0.00
BITS										
1593997	449628	118977	193415	65424	174535	112160	163989	95533	165212	55124
3200002	464512	130252	149247	104362	160340	102861	165408	101913	163908	63202
4788016	512892	155121	118955	82871	173750	77068	162038	92928	160802	51589
6392256	493813	233546	90678	55896	189730	111278	127934	101923	148521	50921
8015330	472638	285404	89032	45631	147964	136565	155802	69555	157258	63225
9573555	499596	218768	85568	76137	144108	95801	163770	68248	158945	47284
11204676	441632	139980	190297	66174	188109	115695	157599	108559	172745	50331
12794754	421503	238539	91032	73231	192160	99283	146525	111568	155702	60535
14392676	479741	165664	149714	65390	171888	96535	175425	59487	188766	45312
15995918	466409	208248	125415	54177	192652	92026	156456	100762	151608	55489
17591342	481754	239516	112796	54922	145856	118799	153165	70627	168217	49772
19194250	476101	174179	161614	55503	152724	132953	157371	84014	151349	57100
0	499009	178242	150886	50796	168993	0	0	0	0	0

21. Annex B: Listing of sizes of bitstream files.

```
Directory KODING$DUA1:[USER0.SIM.GISLE]

FLOWER4.;1           4955
MOBCAL4.;1           4954
TENNIS4.;1           4949
FLOWER9.;1          11156
MOBCAL9.;1          11108
TENNIS9.;1          11111
POPPLE9.;1          11030

Total of 7 files, 59263 blocks.
```

One block is 512 Bytes = 4096 bits.